

SOLVENTS, OILS, GUMS, WAXES

AND

ALLIED SUBSTANCES

BY

FREDERIC S. HYDE, PH.B.

*Formerly Assistant Chemist, Brooklyn Health Department; Late Assistant
in Analytical Chemistry, Columbia University; Late Chemist,
Dixon Crucible Company, Jersey City, N.J.;
Consulting Chemist, New York.*

LONDON:

CONSTABLE & COMPANY, LTD.

10 ORANGE ST., LEICESTER SQ., W. C.

1915

1605

634

111

COPYRIGHT, 1913,
BY
D. VAN NOSTRAND COMPANY

PREFACE

THESE notes are intended for the use of factory chemists and others who may desire a short reference book on commercial organic products. The subject-matter has been compiled from various sources and purposely condensed to render it the more accessible. Reference is made to well-known authorities throughout the text. Only those methods and tests which seemed reliable in the hands of the writer have been selected, limiting the descriptions to the salient features in each case.

F. S. H.

NEW YORK, *Aug. 15, 1913.*

TABLE OF CONTENTS

	PAGE
PREFACE.....	iii
VARIOUS SOLVENTS AND FLUIDS. Aldehydes, Alcohols, Ethers, and Benzol Derivatives, with special tests.....	1-22
TERPENE BODIES, CAMPHORS, ESSENTIAL OILS, FRAGRANT SUBSTANCES, AND BALSAMS. Terpene Bodies: Turpentine and Venice Turpentine. Camphors: Laurel Camphor, Menthol, Peppermint, and "Coal Tar Camphor." Essential Oils: Anise, Bergamot, Bitter Almonds, Cinnamon, Citronella, Cloves, Sassafras, and Wintergreen. Fragrant Substances: Cumarin and Vanillin. Balsams: Canada, Copaiba, Peru, Styrax, Tolu, and Gum Benzoin.....	22-33
TRUE GUMS, GUM RESINS, AND BITUMENS. Arabic, Tragacanth, Copal, Kauri, Shellac, Rosin, Asphalt, Pitch, etc.....	33-42
CARBOHYDRATES. Sugars, Starch, Dextrin, Cellulose, etc., with tests.....	42-51
ALBUMENOIDS AND PROTEIDS. Albumen, Casein, Gluten. Proteoids or Collagens as Gelatine and Glue.....	51-55
OILS, FATS AND WAXES. Saponifiable and Non-saponifiable Matter. Koettstorfer Process. Acid and Ester Number. Reichert Distillation for Volatile Fatty Acids. Acetylation. Iodine Absorption by Hübl, Wijs, and Ianus Methods. Table of Approximate Figures. Adulterations in Butter and Milk.....	55-69
LIST OF COMMERCIAL TESTS ON OILS AND FATS. Comparisons of Oils and Fats with Derivation, Constants, Solubilities, etc. Group Table of Principal Oils according to Specific Gravity and Constants.....	69-89
LUBRICATING OILS. Sperin, Lard, Tallow, and Neatsfoot Oils; Horse Fat, Bone Tallow, Rosin Oils, and Analysis of Greases.....	90-96
LINSEED OIL. Adulterants. Important Tests. Bromine Absorption. Boiled Oil. Proportion of Driers. Paint Analysis.....	97-109
INSOLUBLE SOAPS. Metallic Oleates, Stearates, and Palmitates. Insoluble Linoleates. Preparation of Resinates.....	109-117
FATTY ACIDS. Separation by Precipitation. Determination of Melting-point. Separation of Mixed Fatty and Resin Acids....	118-122

	PAGE
WAXES. Descriptions. Solubilities. Specific Gravities. Melting-points. Qualitative Tests. Saponification. Table of Comparisons. Wax Acids and Higher Alcohols. Tests on Cholesterol, Phytosterol, and Sitosterol.....	122-143
ALKALOIDAL SUBSTANCES. Ptomaines. Table of Vegetable Alkaloids. Immiscible Solvents, Solubilities, Reagents, and Tests.....	144-151
BITTER PRINCIPLES. Glucosides and Non-glucosides, with tests.	151-154
MISCELLANEOUS SUBSTANCES. Identification of Acetanilid, Phenacetin, Quinine, Salol, etc. Thalleioquin Test. Preparation of Sodium Nitroprusside. Scheme for Organic Substances. Scheme for Hair Tonics, Cologne Water, etc. Separation of Alkaloids and Glucosides. Normal Acid and Alkali Solutions. The Composition of Red Lead.....	154-170
INDEX.....	171-176

SOLVENTS AND OILS

VARIOUS SOLVENTS AND FLUIDS

Methylal, or Formal. $\text{CH}_2(\text{O.CH}_3)_2$. Methylene-dimethyl-ether. Produced by the oxidation of methyl alcohol with manganese dioxide and sulphuric acid. A volatile liquid with ethereal odor, boiling at 42°C ., sp. gr. 0.855 at 15°C . Miscible with alcohol, ether, and water. Possesses hypnotic and anæsthetic properties, and has a limited use as a solvent or medium for extracting fine perfumes.

Formaldehyde. H.CHO , or CH_2O . A well-known disinfectant, germicide, antiseptic, and reducing agent. Used in the gaseous form or in aqueous solution. Very volatile. "Formalin" is a 30 to 40 per cent solution of formaldehyde gas in water, with a specific gravity of from 1.080 to 1.088. Formaldehyde may be prepared by passing the vapors of methyl alcohol over a glowing platinum or copper spiral; or by the distillation of calcium formate; or by adding water to a mixture of methylal and sulphuric acid and distilling the same, whereby aqueous formaldehyde is produced. The gas has a pungent odor and is miscible with water in all proportions. Incompatible with ammonia and bi-sulphites, as well as solutions of silver, copper, and iron. It may be recognized by the reddish-violet color formed when overlaid with a sulphuric acid-ferric chloride solution, or by the blood-red tint when heated with a little salicylic acid in sulphuric acid, or by the "silver mirror" formed when heated with ammoniacal-silver nitrate. A

1 to 2 per cent solution is quite effective and has no deleterious action on animal tissues.

Uses:—It has been employed as a preservative to prevent putrefaction, as with casein. Has a tendency to harden proteid matter and render it impervious to moisture. Used for preserving and hardening anatomical specimens and in surgery for general antiseptis. For disinfecting rooms, books, utensils, etc., a special lamp is employed to produce the vapors. Also used as a chemical reagent. Commercially known under the name of "formalin," a 35 to 40 per cent aqueous solution.

FORMALDEHYDE AND FORMATE TESTS

Silver-reduction Test:—(a) Dissolve 1 part silver nitrate in 10 parts of concentrated ammonium hydrate (sp. gr. 0.923). (b) Prepare a 10 per cent solution of caustic potash or soda. In an absolutely clean test-tube (previously cleaned with hot caustic-potash solution) mix 1 c.c. each of (a) and (b). Shake and allow a few drops of formaldehyde or formate solution to flow slowly down sides of tube into the reagent. Shake and let stand cold 5 minutes. A dark precipitate or "silver mirror" indicates a formate of formaldehyde. Caution! If the ammonia-silver-potash reagent is mixed in advance, it must be kept cool, otherwise an explosive precipitate may occur on standing. Similar results may be obtained by using 10 c.c. of a silver nitrate solution (about 0.5 gram per 100 c.c.), to which is added a sodium carbonate solution to precipitate Ag_2CO_3 , yellowish white, and then adding one or two drops strong ammonia just sufficient to dissolve the Ag_2CO_3 on shaking. This solution is quite sensitive to formaldehyde.

Resorcin Test:—Mix one drop 1 per cent aqueous resorcin solution with one c.c. dilute (0.2 per cent) aqueous formaldehyde. Allow this mixture to flow gently down the side of

an inclined test-tube containing from 3 to 5 c.c. pure concentrated sulphuric acid. Slowly rotate lower end of tube so as not to mix the layers. A red or rose-colored zone overlaying the acid indicates formaldehyde.

Sodium-nitroprusside Test:—Use dilute aqueous solution of nitroprusside, slightly alkaline with caustic soda.

Formaldehyde, dark amber tint.

Acetaldehyde, red, becoming darker on standing.

Acetone, claret red, fading slowly to orange.

Quantitative Estimation (Romijn's Method):—Potassium cyanide reacts with formaldehyde to form an addition-product which does not affect silver nitrate in presence of nitric acid. Using a known amount of cyanide, any excess reacts with silver nitrate and may be titrated with N/10 ammonium thiocyanate, using ferric ammonium sulphate as indicator, the difference representing cyanide taken up by formaldehyde. (For details, consult Sherman's Organic Analysis.)

Acetaldehyde. CH_3CHO . Ethyl aldehyde. From the oxidation of ethyl alcohol. A mixture of 16 weights of dilute sulphuric acid (1 : 6) and 3 weights of absolute alcohol is allowed to drop slowly upon 2.8 weights of sodium bichromate, using a stop-cock funnel fitted to a large flask which is also connected with a reflux condenser inclined upwards, so that only aldehyde vapors pass over, while the flask is gently warmed over a water-bath. On account of its great volatility, the aldehyde is collected in absorption tubes containing ammoniacal ether, whereby aldehyde-ammonia is slowly deposited as a crystalline compound. From the latter, the aldehyde may be liberated by distilling with dilute sulphuric acid and condensing the vapors with ice water.* It is a colorless liquid with pungent odor.

* See Remsen's Organic Chemistry, Gattermann's Die Praxis des organischen Chemikers, and Richter's Organic Chemistry.

Sp. gr. 0.790 at 15° C. B. P. 20.8° C. Invariably found in commercial alcohol, and its presence in alcoholic-potash solutions is denoted by the yellow or brown color produced on standing some time, due to the formation of an "aldehyde-resin" together with an alkaline formate and acetate.

Aldehyde may be removed from alcohol by shaking with a little powdered potassium permanganate and allowing to stand for a while, whereby brown manganese hydrate settles out. A little precipitated chalk is then added to the liquid and the alcohol slowly distilled, rejecting the first portions of the distillate until they no longer produce a yellow color when heated with caustic potash.

Acetaldehyde readily reduces Fehling's solution and precipitates ammoniacal-silver nitrate with formation of a "mirror." It also yields crystalline compounds with bisulphites.

Uses:—For the preparation of paraldehyde employed in medicine.

Furfurol. $C_4H_3O.CHO$. An aldehyde produced by distilling wheat bran, sugar, starch, or other carbohydrates with dilute sulphuric or hydrochloric acid. It may be separated from the distillate by "salting out" with common salt and repeating the distillation.* The hexoses (as sucrose, starch, dextrose, levulose, etc.) yield considerable levulinic acid and little furfurol, while the pentoses (as xylose and arabinose) yield no levulinic acid and much furfurol.† The pentosans, or pentose anhydrides (such as araban in cherry gum and gum arabic and xylan in wheat bran and various cereals) also yield considerable furfurol as compared with sucrose and starch. It is also a constituent of crude distilled spirits and occurs in crude

* Fownes' Elementary Chemistry; Richter's Organic Chemistry.

† See Sherman's Organic Analysis.

acetic acid and fusel oil.* Furfurol, when fresh, is a colorless aromatic fluid. B. P. 162° C. Sp. gr. 1.163 at 13° C. Darkens on exposure to air. Soluble in 12 parts water at 13° C.; easily soluble in alcohol. Possesses all the properties of aldehydes.

Test for Furfurol:—Boil a quantity of sugar in an Erlenmeyer flask with dilute hydrochloric acid (sp. gr. 1.06) and place over the mouth of the generating flask a strip of filter paper moistened with a solution of anilin acetate (made from equal volumes of 50 per cent acetic acid and anilin). A bright red coloration should be produced by the escaping vapors. Furfurol also imparts a red color to sesamé oil (Baudoin's Test).

Quantitative Estimation:†—Distil 3 grams of material with 100 c.c. 12 per cent HCl (sp. gr. 1.06) until 30 c.c. pass over, add more acid (30 c.c.) and continue distillation so long as the distillate gives red color with anilin acetate on filter paper. To entire distillate add phloroglucin (free from di-resorcin) dissolved in 12 per cent HCl; stir well. Color changes from yellow to green, soon followed with an amorphous green precipitate turning almost black. Collect and wash phloroglucin on tared Gooch (asbestos felt). Dry from 3 to 4 hours at 100° C. to constant weight. For furfurol divide weight phloroglucin (up to 0.2 gram) by 1.82; (from 0.2 to 0.3 gram) by 1.895; (from 0.3 to 0.4 gram) by 1.92; and (above 0.4 gram) by 1.95. To the weight of furfurol found add a correction of 0.0104 gram for solubility.

Methyl Alcohol. CH_3OH . Wood alcohol. Inflammable. B. P. from 55° C. to 65° C. Sp. gr. about 0.8021 at 15.5° C. When impure, it has an empyreumatic odor which is not present in the pure. Combines with fused

* Comm. Org. Anal.

† Sherman's Organic Analysis and Bull. No. 46, Bur. Chem., U. S. Agric. Dep't.

calcium chloride by which it may be purified. Miscible with water in all proportions. Its solvent action is similar to that of grain alcohol.

Ethyl Alcohol. $C_2H_5.OH$. Grain or whiskey alcohol. Inflammable. B. P. $78^{\circ}C$. Sp. gr. 0.7938 at $15.5^{\circ}C$. Solvent for resins, essential oils, soaps, phenol, camphor, glycerol, iodine, and many salts including metallic chlorides (except Ba), bromides, iodides, acetates, and caustic alkali. The carbonates (except Cs), borates, phosphates, sulphates, oxalates, and tartrates are insoluble in alcohol; sulphur and phosphorus are slightly soluble. Nitric and chloric acids act violently. Sulphuric, hydrochloric, acetic, and oxalic acids form "ethers."

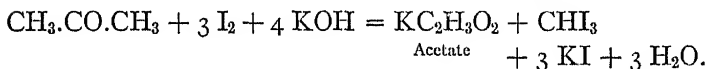
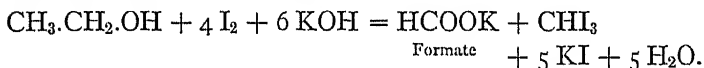
Acetone. $CH_3.CO.CH_3$. Di-methyl-ketone. Inflammable. B. P. $56.3^{\circ}C$. Sp. gr. 0.797 at $15^{\circ}C$. Produced by dry distillation of calcium acetate. Solvent for fats, oils, resins, gums, camphor, and gun cotton. Miscible in all proportions with alcohol, ether, and water. Unites with bi-sulphites to form crystalline compounds. May be separated from methyl alcohol by calcium chloride which combines with methyl alcohol, using an excess of fused chloride to form the compound $CaCl_2.4 CH_3OH$. Stable at $100^{\circ}C$. The acetone is removed by distilling on a water-bath, after which water is added to take up the $CaCl_2$ and the distillation continued for methyl alcohol.

TESTS ON METHYL AND ETHYL ALCOHOLS, ACETONE, AND ALDEHYDE

Iodoform Test:— CHI_3 is formed from ethyl alcohol, acetone, and acetaldehyde; but not from pure methyl alcohol nor from ethyl ether. The solution should contain only a small amount of alkali to insure success.*

* For details consult Sherman's Organic Analysis.

Lieben's Method (best): — To 10 c.c. clear liquid to be tested, or to the same quantity of 10 per cent alcohol or acetone solution, add from 5 to 10 drops aqueous 10 per cent caustic potash. Warm to 50° C., and slowly add a saturated solution of iodine in potassium iodide until a permanent yellow-brown tint results with separation of iodoform (CHI_3). Then carefully decolorize by adding, drop by drop, more 10 per cent KOH, until the solution clears and canary yellow precipitate settles.



Dilute sodium-carbonate solution may be substituted for the caustic potash above but is not so effective. Pure methyl alcohol alone does not give the precipitate, but with acetone present iodoform is readily formed.

N.B. — Iodoform is used as an antiseptic dressing in hospital and dispensary work. It has a strong persistent odor, is soluble in alcohol, insoluble in water, and volatile with steam.

Bichromate Oxidation: — Dissolve 1 part potassium bichromate in 20 parts water, acidify with 1 part concentrated sulphuric acid, cool the solution, and add alcoholic fluid (or $\frac{1}{10}$ volume of alcohol as such). The operation may be performed in a large test-tube. Let stand. The color becomes dark red, finally changing to green, with the formation of chrome alum, $\text{K}_2\text{Cr}_2(\text{SO}_4)_4 \cdot 24 \text{ H}_2\text{O}$, in solution. Note pungent odor of aldehyde. By this means, methyl alcohol is oxidized first to formaldehyde, then formic acid; and ethyl alcohol to acetaldehyde and acetic acid.* The reaction may be hastened by heating, but liable to drive

* Perkin's Organic Chemistry, 1911, Part 1, pp. 95, 99.

out acetaldehyde. Both formic acid and formate, as well as formaldehyde and acetaldehyde, reduce ammoniacal silver solution; not so, acetic acid nor acetate. Remove the chromium (when reduction is complete) by precipitation with slight excess of sodium-carbonate solution and boil out aldehyde, leaving formate in solution. Filter and reserve filtrate for tests.

Chloroform. CHCl_3 . Tri-chlor-methane. Anæsthetic. Non-inflammable liquid—heavy vapors. Sp. gr. 1.5 at 15°C . B. P. 61°C . Produced by the action of bleaching powder on alcohol or acetone, the latter cheaper and better; also from chloral hydrate and potash; and by reduction of carbon tetrachloride with zinc and hydrochloric acid. Possesses an ethereal odor and sweet taste. Miscible in all proportions with alcohol, ether, benzol, and petrolic ether, but not with water. Solvent for fats, oils, resins, camphor, sulphur, phosphorus, iodine, the latter imparting a violet tint. Retards putrefaction and fermentation in certain liquids (notably urine).

Carbon Tetrachloride. CCl_4 . Tetra-chlor-methane. Non-inflammable, heavy, colorless liquid. Sp. gr. 1.6 at 15°C . B. P. 77°C . Prepared by passing mixed vapors of carbon bi-sulphide and chlorine through a red hot porcelain tube, or by passing chlorine through carbon bi-sulphide containing iodine. Its odor is rather aromatic. Immiscible with glycerine and water. Miscible with absolute alcohol, acetone, chloroform, ether, benzol, benzine, carbon bi-sulphide, sulphur chloride, turpentine, and oils. Solvent for fats, oils, resins, soaps (K and Na), rubber, asphalt, wax, camphor, tarry bodies, phosphorus, sulphur, iodine, bromine, chlorine, etc., as well as phenol, paraffin, naphthalene, and other bodies. It is a great cleansing agent, and on account of its fireproof qualities has been used as a substitute for benzine. In proper ad-

mixture it will render naphtha, gasoline, or turpentine non-inflammable at ordinary temperature. Useful in the manufacture of varnishes, rubber cements, and "paint removers." On evaporation, it should leave no odor or residue. Incompatible with hot alcoholic potash, forming water, chloride, and carbonate.

TESTS ON CHLOROFORM AND CARBON TETRACHLORIDE

1. Each possesses a characteristic ethereal odor, and both are heavy liquids.

2. Chloroform has a sweet taste; carbon tetrachloride, a flat, fugitive taste.

3. Boiling-point of chloroform, $61^{\circ}\text{C}.$; boiling-point of carbon tetrachloride, $77^{\circ}\text{C}.$

4. A piece of filter paper, soaked in chloroform and ignited, gives vapors of HCl and white fumes on exposure to ammonia on a glass rod. Likewise with carbon tetrachloride; but the action is more marked and the paper more difficult to ignite.

5. Chloroform reduces Fehling's solution on boiling. Not so with carbon tetrachloride, the solution remaining clear blue.

6. Caustic-potash solution (aqueous or alcoholic) and acetanilid, heated with few drops of chloroform, produce the fetid odor of phenyl-isocyanide ("isonitril test"). Not so with carbon tetrachloride, the odor remaining unchanged.

7. Equal parts of aqueous caustic potash, resorcin and chloroform, boiled in a test-tube, give a cherry-red color. Carbon tetrachloride may produce an olive color, especially if alcoholic potash be employed.

8. Boil chloroform and aqueous caustic potash in a test-tube until solution is clear, whereby potassium formate and chloride are produced. (Alcoholic potash gives ethyl formate and KCl). Acidify slightly with nitric acid and

add a few drops silver-nitrate solution, which should give a white, curdy precipitate of silver chloride. With carbon tetrachloride the action is slow and not so pronounced, producing KCl , H_2O , and CO_2 , the latter absorbed by caustic potash to form carbonate, but no formate. On acidifying with slight excess of nitric acid CO_2 is liberated; and on adding silver-nitrate solution, a small precipitate of silver chloride is produced.

Chloral. CCl_3CHO . Tri-chlor-aldehyde. Anhydrous chloral, as such, is a colorless, limpid liquid with sharp odor. It is produced by passing chlorine into alcohol and distilling the crystalline product with sulphuric acid.* It boils at 97°C ., and has a specific gravity of about 1.51 at 15°C . But, mixed with the calculated amount of water, it forms chloral hydrate — $\text{CCl}_3\text{CH}(\text{OH})_2$ — a white crystalline solid, melting at 57°C ., easily soluble in water, and possessing a peculiar odor, sharp taste, and powerful hypnotic properties. It distils at 98°C ., breaking up into chloral and water. The hydrate liquefies when triturated with an equal quantity of camphor.

Tests for Chloral: — Warmed with ammoniacal silver nitrate in a clean test-tube chloral forms a "mirror." Heated with caustic potash it gives a chloroform odor and formate in solution, the latter on heating with H_2SO_4 evolving CO free from CO_2 . Boiled with caustic potash and a pinch of resorcin it gives an intense red color. Mixed with a 5 per cent phenol solution and an equal volume of H_2SO_4 , it gives a pink color. Boiled with strong caustic potash and a pinch of acetanilid or a drop of anilin it should produce a peculiar fetid isonitril odor. Reduces Fehling's solution.

Acrolein. $\text{CH}_2\text{:CHCHO}$. Acrylic aldehyde. Produced by distilling glycerine with potassium sulphate, and noticed in the pungent odor of burning fat. The vapor causes a

* Perkin's Organic Chemistry.

copious flow of tears. The fluid boils at 52° C. and has a specific gravity of about 0.84. It reduces Fehling's solution as well as dilute silver nitrate, and forms a resinous body with caustic alkali.

Ether. $C_2H_5.O.C_2H_5$. Sulphuric ether, or di-ethyloxide. Anæsthetic. A colorless liquid with a characteristic odor and boiling at 37° C. Specific gravity 0.725 at 15° C. Produced by distilling alcohol and sulphuric acid in proper proportions. Its vapors are heavy and very inflammable. Solvent for fats, oils, and resins, but not for sugars. It also dissolves iodine, bromine, phosphorus, sulphur, paraffine, and many alkaloids; likewise certain salts, as $HgCl_2$, $FeCl_3$, $AuCl_3$, and HgI_2 .*

Miscible with alcohol, benzine, chloroform, and to some extent with water. If ether itself contains alcohol, its volume will diminish on shaking with water which extracts the alcohol.

Petrolic Ether. Light petroleum distillate. (Gasoline.) Mostly pentane and hexane, C_5H_{12} and C_6H_{14} . B. P. about 50° C. Sp. gr. from 0.650 to 0.700. Inflammable and very volatile, with odor somewhat like onions and very pronounced. Solvent for certain fats and oils, especially the non-drying oils, mineral oils, sugar, resins, etc., with the exception that castor oil is insoluble. Oxidized drying oils as paint skin and linoxyn are insoluble.

Ordinary K or Na soaps are *practically insoluble* in petrolic ether. Cold petrolic ether is immiscible with phenol, but dissolves beechwood creosote. It is miscible with absolute alcohol, glacial acetic acid, and most solvents except water.

Benzine. Petrolic benzine. Refined naphtha. Inflammable. A mixture of fatty hydrocarbons, principally hexane, C_6H_{14} , and heptane, C_7H_{16} . Sp. gr. from 0.68 to 0.72. B. P. from 70° C. to 90° C. Must not be confounded with

* See Allen, Vol. I, p. 124.

b-e-n-z-e-n-e, or benzol, a totally different liquid derived from coal tar. Similar to petrolic ether as solvent for oils and greases. Also used as a substitute for turpentine in paints, varnishes, and driers.

Carbon Bi-sulphide. CS_2 . Inflammable liquid with disagreeable, rotten-egg odor. Colorless, when pure, and highly refractive to light. Prepared by passing vapors of sulphur over red-hot charcoal. Sp. gr. 1.29 at 0°C . B. P. 46°C . Solvent for caoutchouc, phosphorus, sulphur, fatty oils, vaseline, bromine, and iodine, the latter imparting a violet-red color. It may be purified and its odor rendered more agreeable by treatment with bromine, subsequently removing the bromine with a slight excess of potash, then agitating with a little potassium chloride to destroy any opalescence, and finally filtering the bi-sulphide.* Miscible with alcohol, ether, chloroform, and benzol, but not with water. Useful for extracting essential oils, spices, and perfumes. Commonly used for the preparation of rubber cement.

Sulphur Chloride. S_2Cl_2 . Sulphur monochloride. Yellowish-red, oily, fuming liquid with pungent odor, and irritating to the eyes. Sp. gr. from 1.68 to 1.70 at 0°C . B. P. 138°C . Prepared by passing dry chlorine over heated sulphur in a retort, allowing the compound to distil into a receiver. With water it disassociates into HCl , SO_2 , and S . Miscible with carbon tetrachloride, carbon bi-sulphide, benzine, benzol, etc. Specially used in the cold vulcanization of rubber, preparation of rubber substitutes, and the thickening of fish oil, corn oil, etc., as substitutes for linseed oil.

Fusel Oil. From the alcoholic fermentation of corn, rye, potatoes, barley, etc. A mixture of higher alcohols, containing ethyl alcohol, isoamyl alcohol, isopropyl alcohol, aldehyde, etc. Chiefly used as a solvent for manufacturing purposes and as a source for amyl alcohol.

* See Vulte and Neustadt, *Inorganic Preparations*,

Amyl Alcohol. Potato spirit. Isoamyl alcohol. $(\text{CH}_3)_2\text{CH}.\text{CH}_2.\text{CH}_2.\text{OH}$. Present in fusel oil. Sp. gr. 0.8148 at 14°C . B. P. 131°C . Obtained by mixing fusel oil with strong brine, separating the oily layer, distilling, and collecting the portion coming over between 128°C . and 132°C . Miscible in all proportions with alcohol, ether, chloroform, petroleic ether, benzol, etc. Soluble in water, 1 to 39 at 60°C .; but, 11.6 parts of amyl alcohol absorb 1 part of water. A few drops internally produce injurious intoxicating effects. Solvent for oils, camphor, resins, and alkaloids (such as morphine); also for sulphur, phosphorus, and iodine. Used in producing artificial fruit essences and perfumes.

Amyl Acetate. Artificial banana oil. $\text{C}_5\text{H}_{11}.\text{O}.\text{C}_2\text{H}_3\text{O}$. Prepared by distilling amyl alcohol with sodium acetate and sulphuric acid. Colorless liquid with fragrant odor when pure. Sp. gr. 0.8763 at 15°C . B. P. 137°C . Insoluble in water. Miscible in all proportions with alcohol, ether, and amyl alcohol. Solvent for gun cotton (pyrox-lylin) and various resins. Under the name of banana oil (known to painters), it is used for the preparation of lacquers, collodion varnishes, and bronzing liquids. Does not attack the bronze.

Glacial Acetic Acid. $\text{CH}_3.\text{COOH}$. Pure acetic acid. A clear liquid with sharp vinegar odor, crystallizing at a low temperature, and having a melting-point of 16.7°C . It takes up water with evolution of heat, contracting in volume until about 80 per cent strength is reached.

Oudemann* has shown that

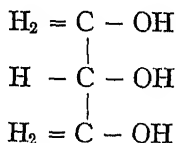
100 per cent acetic acid has a specific gravity of 1.0553 at 15°C .
90 per cent acetic acid has a specific gravity of 1.0713 at 15°C .
70 per cent acetic acid has a specific gravity of 1.0733 at 15°C .
40 per cent acetic acid has a specific gravity of 1.0523 at 15°C .

* Allen, Vol. I, 1898, p. 380.

Therefore, the specific gravity does not necessarily denote the strength of acid. The 100 per cent acid has a boiling-point of 118°C . The 99.5 per cent U. S. P. glacial acetic acid should have a specific gravity of about 1.058 at 15°C . and boiling-point of 117°C . Miscible with alcohol, ether, and water. Solvent for essential oils, phenols, resins, gelatine, castor oil, and rosin oil, but *not* for mineral or rape oils. Very stable — not affected by chromic or nitric acids or permanganates. With chlorine it forms the chlor-acetic acid, $\text{Cl}.\text{CH}_2.\text{COOH}$. Used in oil analysis to separate mineral from rosin oil and also for the Valenta turbidity test.

Acetic Anhydride. $(\text{CH}_3\text{CO})_2\text{O}$. Acetyl oxide. Colorless liquid with penetrating pungent odor. Sp. gr. 1.08 at 15°C . B. P. 137°C . Prepared by distilling anhydrous sodium acetate and acetyl chloride. Miscible with water, forming acetic acid. Immiscible with fatty and mineral oils. Solvent for rosin oil, resinous matter, and cholesterol. Used in the Liebermann-Storch test for rosin oil, also in the analysis of glycerine by the "Acetin Method," and for the "Acetylyzation of Fats and Waxes."

Glycerine. $\text{C}_3\text{H}_5(\text{OH})_3$. Propenyl hydrate. "Glycerol." A tri-atomic alcohol from the saponification of fats. Its constitutional formula is:



Clear, viscous, non-odorous liquid possessing a sweet taste. It is volatile with steam. Sp. gr. (anhydrous) 1.265 at 15°C . At 290°C ., B. P., it decomposes producing vapors of acrolein. It also absorbs moisture from the air. Miscible with alcohol and water. Insoluble in ether, chloro-

form, benzol, and fixed oils. Dissolves alkalies, alkaline earths, and many metallic oxides. Solvent for phenol, iodine, mercuric iodide, boric acid, arsenious oxide, and salts of copper. Treated with potassium bichromate and sulphuric acid, it is completely oxidized to carbon dioxide and water. Heated gently with solid caustic potash, it produces potassium acetate and formate.

Separation of Glycerine from other Substances: — A mixture of

Absolute alcohol	2 volumes
Pure ether	1 volume

will separate glycerine from sugars, gums, dextrine, gelatine, and various salts. In similar manner, glycerine is soluble in a mixture of equal weights of chloroform and alcohol in which the sugars, gums, and dextrine are insoluble.*

TESTS FOR GLYCERINE, OR GLYCEROL†

Heated with KHSO_4 , glycerine produces an irritating odor of acrolein, causing flow of tears. If the acrolein vapors are conducted into water, the solution will reduce ammoniacal silver-nitrate solution, forming a "mirror" on walls of test-tube. If a mixture of two drops pure glycerine, two drops pure phenol, and two drops concentrated sulphuric acid, be placed in a dry test-tube and heated very carefully to 120°C. , a brownish-yellow mass results, which, on cooling and dissolving in faintly ammoniacal water, should produce a beautiful carmine-red coloration.

* See Allen, 1899, Vol. II, part 1, p. 304.

† For the quantitative determination of glycerol by the "Acetin Method" consult Lewkowitsch, Analyst, 1903, p. 325; J.S.C.I., 1903, p. 576; also "Report of the Sub-Committee on Glycerine Analysis," Langmuir, Jour. Ind. & Eng. Chem., 1911, p. 679. See under "Acetylation Test."

Flame Test:—The glycerine solution should be made slightly alkaline with soda, then poured upon powdered borax in a watch-glass. Dip a platinum wire loop into it, and test in a Bunsen flame which should exhibit a greenish tinge if glycerine be present.*

Benzol. C_6H_6 . Benzene from coal tar. Nucleus, or starting-point, for "aromatic" compounds in organic chemistry. A colorless, highly refractory liquid with characteristic aromatic odor and inflammable vapor. B. P. $80.5^\circ C$. Sp. gr. 0.899 at $0^\circ C$. Lighter than and insoluble in water. Miscible with alcohol, ether, petrolic ether, chloroform, turpentine, absolute phenol, oils, fats, and waxes. Solvent for sulphur, phosphorus, iodine, and rubber. Basis for most "paint removers" (loosening paint). No reaction with metallic sodium.

Nitro-benzol. $C_6H_5.NO_2$. Oil of mirbane. Poisonous. Possesses odor of bitter almond oil, but is of different composition. A light yellowish oil. Sp. gr. 1.18 at $15^\circ C$. B. P. $205^\circ C$. Insoluble in water, but soluble in nitric acid from which it may be precipitated on dilution. Miscible with alcohol, ether, and oily substances. By reduction, gives anilin. Used for scenting greases, soaps, and polishes; also, in analysis as a solvent for certain anilin colors.

Toluol. $C_6H_5.CH_3$. Toluene. Methyl-benzol. From coal-tar distillation and also from the dry distillation of tolu balsam. Very similar to benzol. Sp. gr. 0.87 at $15^\circ C$. B. P. $110.3^\circ C$. Miscible with alcohol, ether, glacial acetic acid, and acetone. Used in deriving coal-tar colors and artificial musk. Solvent for crude rubber.

Anilin. Amido-benzol. $C_6H_5.NH_2$. From the reduction of nitro-benzol with iron and hydrochloric acid. A colorless, highly refractive liquid, when fresh, with faint fetid odor. Darkens on exposure. Sp. gr. 1.026 at $15^\circ C$.

B. P. 183° C. Slightly soluble in water. Easily soluble in alcohol and ether. Colored purple by solution of "bleaching powder."

Uses: — Production of anilin colors (dyestuffs), solvent for rubber and for softening paint skins.

Gas Tar or Coal Tar. A brownish black oily liquid with strong tarry odor. Sp. gr. about 1.15. Besides some water and ammoniacal liquor, it contains benzol, toluol, xylol, phenol, naphthalene, coal-tar pitch, etc., all of which may be separated by fractional distillation. *

Uses: — Making "tar-paper," preserving timber, painting gas tanks, condensers, etc. The anhydrous tar is used for ramming furnace linings (magnesite), where moisture would be detrimental. Note, for proximate analysis, that:

(1) Any water present should be separated by rotation or gyration before distillation.

(2) Method of distillation depends on the character of the tar and the number of "fractions" desired.

(3) Wood tars are acid, while coal, shale, and bone tars are alkaline.† Example of fractioning coal tar:

- | | |
|---------------------------------|---|
| I. Crude naptha | $\left\{ \begin{array}{l} 0^{\circ}-110^{\circ} \text{ C. "90 per cent benzol"} \\ 110^{\circ}-170^{\circ} \text{ C. xylol, cumol, toluol} \end{array} \right.$ |
| II. "Creosote oils" | $\left\{ \begin{array}{l} 170^{\circ}-225^{\circ} \text{ C. phenols} \\ 225^{\circ}-270^{\circ} \text{ C. naphthalene} \end{array} \right.$ |
| III. Anthracene oil ("red oil") | $-270^{\circ} \text{ C. and above.}$ |
| IV. Pitch. | |

The first "fractions" may be redistilled to recover volatile hydrocarbons retained by those of higher boiling-points. Phenols are removed by treating the "creosote" portion with caustic alkali.‡

* Thorp's Ind. Chem., 1899, p. 283.

† Allen, 1900, Vol. II, part 2, p. 37.

‡ Allen, 1900, Vol. II, part 2, pp. 300, 302.

Phenol. "Carbolic acid." C_6H_5OH . Anhydrous pure, forms crystalline white needles. Liquefies in air. Characteristic, penetrating odor and burning taste. Poisonous and antiseptic. Whitens the skin. Found in coal-tar creosote. Prepared synthetically by fusing potassium benzol sulphonate with caustic potash, and treating melt with hydrochloric acid to liberate phenol. Pure crystals. M. P. $42^\circ C$. B. P. $183^\circ C$. Soluble in 15 parts water at $20^\circ C$., the solubility increased by glycerine. Almost insoluble in cold petrolic ether. Very soluble in alcohol, ether, chloroform, and glacial acetic acid.

Tests for phenol:

1. Odor characteristic in small amounts.
2. Ferric chloride (neutral), one drop added to 10 c.c. of 1 per cent aqueous phenol solution gives violet tint. (Wood creosote gives transient slaty green to reddish brown precipitate.)
3. Bromine water added to aqueous solution produces a white precipitate of tri-brom-phenol. (Wood creosote gives reddish brown precipitate.)
4. Equal volumes of phenol and glycerine give a clear solution miscible with 3 volumes water. (Wood creosote, similarly, gives turbid liquid with 1 volume water and separation of creosote globules.)
5. Alcoholic potash (20 per cent KHO), 20 c.c. with 1 c.c. phenol, forms soluble phenate. (Wood creosote gives solid crystalline mass on standing a few minutes.)
6. Collodion forms coagulum on stirring with equal volume phenol. (Wood creosote, clear solution.)

Uses: — Surgical dressings, ointments, disinfectant, etc. With concentrated nitric acid, phenol ultimately forms yellow tri-nitro-phenol or "picric acid." Also employed in the production of coal-tar colors and synthetic drugs.

Coal-tar Creosote. That portion of coal tar distilling between 200° C. and 300° C.* Yellowish fluid with greenish fluorescence. Contains phenol, naphthol, naphthalene, cresol, anthracene, etc. Sp. gr. about 1.10. Strong tarry odor. Poisonous internally. Miscible with solvents, but not with water. Used for preserving timber, for lubricating mixtures, and for illumination, also as an antiseptic detrimental to lower organisms.

Beechwood Creosote. From wood tar; the portion distilling between 150° C. and 250° C. is treated with caustic-soda solution, the aqueous part is drawn off and treated with sulphuric acid to separate the crude creosote, this, in turn, further purified with alkali and acid, then redistilled, saving the fraction between 200° C. and 220° C. as pure creosote.† Contains several phenol bodies, including cresol, guaiacol, and derivatives of pyrogallol. It has a smoky carbolic odor, and is considered non-poisonous. Color yellowish to pinkish. Miscible with most solvents; slightly with water. Nitric acid acts violently. Concentrated sulphuric or hydrochloric acids produce reddish liquids, becoming purple to black on standing. Wood creosote does not coagulate albumen nor gelatinize collodion. (Distinction from phenol.) With alcoholic potash it forms a crystalline mass. (1 c.c. creosote, 10 c.c. 20 per cent absolute alcoholic potash). Used as a source for guaiacol (a remedy for tuberculosis), as an antiseptic, and in dentistry.

Bone Tar. (Dippel's oil.) From the destructive distillation of bones in retorts in the process of making "bone black." A greasy, brownish-black, viscous liquid with an unpleasant pungent "iso-nitril" odor. Besides ammonia, oily matter, nitrils, etc., it contains pyrrol, pyridine, piper-

* Allen, 1900, Vol. II, part 2, p. 294.

† Allen, 1900, Vol. II, part 2, p. 277.

idine, and derivatives. Pyrrol may be easily detected by holding a pine splinter or match-stick, moistened with concentrated hydrochloric acid, directly over the bone tar when the wood should assume a red color. In an experimental extraction of bone tar, the writer obtained 4 per cent pyrrol, 1 per cent pyridine bases, and over 10 per cent tarry matter with disagreeable odor, the rest being more or less saponifiable fatty oils. The pyridine bases had a strong odor of mustard oil and pepper, and fumed strongly in contact with hydrochloric acid vapors.

Uses: — Limited, possible denaturing of alcohol and as an insect poison, and source for pyrrol and pyridine.

N.B. — Bone tar, often called "bone oil," should not be confounded with bone oil obtained by extraction of bones by boiling or with solvents. The latter kind is used in soap making.

Pyrrol. C_4H_5NH , or C_4H_5N . A colorless, aromatic liquid with a chloroform-like odor found in bone tar. It may be prepared synthetically: (1) By passing acetylene and ammonia through a red-hot tube. (2) By distilling succinimid with zinc dust.* It may be separated from bone tar by agitation with dilute sulphuric acid — sufficient to combine with pyridine bases and ammonia and coagulate tarry matter. The acid solution is reserved for pyridine. The residual tarry oil is fractioned, collecting the distillate between $100^{\circ}C.$ and $150^{\circ}C.$, which is then fused with an excess of solid caustic potash in a reflux apparatus, the pyrrol combining with the alkali in a solid mass.†

N.B. — The solid potassium-pyrrol, C_4H_5NK , is decomposed by water, hence would not be formed in its presence.‡ The solid mass is pulverized, washed with ether to remove

* Miller, Jour. Am. Ch. Soc., 1894, p. 436.

† Ber. 19, 173.

‡ Richter's Organische Chemie, p. 581.

oily impurities, then dissolved in water to liberate pyrrol which separates as an oily layer.* It is a very feeble indifferent base, slightly soluble in water, and slowly soluble in dilute acids. Soluble in alcohol, ether, and concentrated acids. Insoluble in alkalies. Sp. gr. 1.077. B. P. 133° C. Imparts purplish red color to pine wood moistened with hydrochloric acid. Becomes discolored (brown) on exposure. Heated in acid solution it forms a red flaky substance, known as pyrrol-red, $C_{12}H_{14}N_2O$. Pyrrol, dissolved in alcohol (1 : 10) and treated with alcoholic iodine (1 : 20), forms tetra-iodo-pyrrol, or "Iodol," a pale yellowish antiseptic, which acts like iodoform without its disagreeable odor.

Pyridine. C_5H_5N . An important constituent of bone tar; the base or nucleus of many alkaloidal substances. A colorless liquid with a penetrating odor. Sp. gr. 0.98 to 0.989 at 15° C. B. P. 115°–116° C. It has a great affinity for water, with which it is miscible in all proportions. Miscible with alcohol, ether, oils, and most solvents. Insoluble in caustic soda or potash (liberated). Pure pyridine has no effect on phenol-phthalein, in distinction from ammonia. Neutralizes strong acids, fumes with concentrated hydrochloric acid, and forms salts as pyridine hydrochloride, picrate, chloroplatinate, and double salts with zinc and cadmium chlorides; also compounds with cupric and mercuric chlorides. For the preparation of pyridine, the acid solution obtained by treating bone tar with dilute sulphuric acid is distilled with steam to remove traces of pyrrol (indicated by pine splinter wet with HCl), then filtered to remove tarry matter, made alkaline with excess of caustic soda to liberate pyridine, and again distilled with steam. The distillate is cooled and an excess of solid caustic soda is carefully added to produce an oily layer of pyridine bases. These are carefully removed and

* Fownes' Elementary Chemistry; Allen, 1892, Vol. III, part 2, p. 113.

slowly boiled with fuming nitric acid to destroy impurities, then again made alkaline with solid caustic, and the liberated bases again removed and retreated with solid caustic until the bases are perfectly anhydrous before attempting fractional distillation.* Anhydrous pyridine has been proposed as a solvent for rubber.† Commercial pyridine contains pyridine hydrate having the formula, $C_5H_5N \cdot 3 H_2O$, which has a constant boiling-point of $94.4^\circ C.$, and very little solvent action.

TERPENE BODIES

Turpentine or Terebenthene. $C_{10}H_{16}$. Often called "Turps" and sometimes oil of turpentine. The pure liquid is obtained by distilling the pine tree gum or wood in a retort with steam of dry heat. The oil passes over while the resinous matter is drawn off from bottom of still and solidified. The solid matter thus obtained is known as rosin or colophonium. A solvent process is also used. There are three varieties of turpentine — American, French, and Russian — all having the same chemical composition, but differing slightly in physical properties, depending on the characteristic "terpene" present. B. P. 156° to $174^\circ C.$ According to Wallach‡ the principal constituent in American and French turpentines is pinene, while in the Russian variety sylvestrine predominates. Turpentine acts strongly on polarized light:

American turpentine. Dextrorotatory.

French turpentine. Lævorotatory.

Sp. gr. averages 0.867 for American and French varieties, the variation being from 0.864 to 0.870 at $15^\circ C.$ Immis-

* Allen, 1892, Vol. III, part 2, pp. 98, 99.

† Jour. Ind. and Eng. Chemistry, 1909, p. 361.

‡ Hurst, Painters' Colors, Oils, and Varnishes.

cible with water. Volatile with steam. Miscible with absolute alcohol, ether, petroleum ether, gasoline, benzol, and bi-sulphide of carbon.

Caution: — Nitric acid acts energetically, almost with explosive violence on turpentine, likewise chlorine, bromine, and iodine. Solvent for fats, oils, and resins. Principal use for thinning paints and varnishes, and also for polishing mixtures. Promotes the drying of paint films through oxidizing properties, and renders the coating more adherent. An excellent medium for determining the specific gravity of other substances insoluble therein.*

Venice Turpentine. An oleo-resinous, thick, sticky, viscous, transparent mass from the larch tree, *Larix europæa* of central Europe. The substance is of about the consistency of clear honey, more viscous than glycerine, and varies in color from water-white to yellowish or greenish. It contains a terpene body, has a mild turpentine odor, and becomes resinous or hard on long exposure. Slowly soluble in absolute alcohol, readily soluble in ether, petrolic ether, acetone, benzol, and glacial acetic acid. Slowly soluble in carbon tetrachloride.

Uses: — Used in fixing colors, enamel painting and firing; also in printing inks, and sometimes in spirit varnishes to impart elasticity. In medicine, for bronchial catarrh and in ointments.

N.B. — Apparently closely related to Canada balsam, which see under "Balsams."

* For manufacture by wood distillation, see article by T. W. Pritchard, *Jour. Indust. and Eng. Chem.*, 1912, p. 338.

CAMPHOR GROUP

Closely related to the Terpenes, but more "saturated."

Laurel Camphor. Common camphor. $C_{10}H_{16}O$. From the camphor tree of China and Japan, and obtained by distilling the wood with steam, forming white masses nearly transparent. Sublimes easily in glistening hexagonal crystals. Slowly volatile at ordinary temperatures. Sparingly soluble in water, on the surface of which small pieces exhibit a rotatory motion. Sp. gr. 0.985 at $15^{\circ}C$. M. P. $175^{\circ}C$. Distils at $204^{\circ}C$. Soluble in alcohol, ether, chloroform, acetic acid, and in oils. The alcoholic solution is dextrorotatory. By reduction with sodium in alcohol ordinary camphor is changed to borneol, or borneo camphor.

Uses: — Moth preventive, celluloid, medicine, lacquers.

Borneol Camphor. Borneol. $C_{10}H_{17}OH$. From Borneo and Sumatra. It is very similar to ordinary camphor, but has a peppery odor. Sp. gr. 1.01 at $15^{\circ}C$. M. P. $198^{\circ}C$. Distils at $212^{\circ}C$. May be oxidized by nitric acid to ordinary camphor, analogous to the oxidation of alcohol to aldehyde. Found in oil of citronella, geranium, etc.

Uses: — Antiseptic, incense, and perfumery.

Menthol or Peppermint Camphor. $C_{10}H_{19}OH$. The principle constituent of oil of peppermint, the essential oil of *mentha piperita*, from which it is obtained crystalline on chilling. It possesses a strong peppermint odor and is levorotatory. M. P. $42^{\circ}C$. B. P. $212^{\circ}C$. Slightly soluble in water. Soluble in alcohol, ether, chloroform, etc.

Uses: — Headache, toothache, catarrh, insect bites, and perfumery.

Oil of Peppermint. Mostly menthol, with some limonene, etc. Varieties, Japanese, American (Wayne Co., N. Y.), and English (Mitcham, Surrey).

Uses: — Medicine and cordials.

Coal-tar Camphor

Napthalene. "Moth balls." Strong tarry odor. $C_{10}H_8$. Not a true camphor, but found in that portion of coal tar distilling between $180^{\circ}C$. and $300^{\circ}C$., and obtained from same by crystallization. Noted for its great volatility, distilling over easily with steam by which it may be purified and afterwards sublimed. Sp. gr. (solid) 1.58. M. P. $79^{\circ}C$. B. P. $218^{\circ}C$. Slowly soluble in cold alcohol; easily, hot. Easily soluble in benzol, acetone, or ether. If boiled with dilute nitric acid, it is oxidized to phthalic acid by destruction of a benzol "ring." With chromic acid mixture napthalene is gradually and completely converted to CO_2 . By leading chlorine gas over napthalene it melts and forms Cl addition-products, such as napthalene-tetrachloride, $C_{10}H_8Cl_4$, which crystallizes from chloroform in large rhomboidal crystals.* Melted napthalene dissolves sulphur, iodine, and phosphorus. It burns with a smoky, luminous flame.

Uses: — Commercially, in the form of "moth balls," for preserving household goods, furs, etc., also as a carburettor for gas lamps, and in the manufacture of dyes. In medicine, used as an intestinal antiseptic and stated to be good for eliminating tapeworms. (Dose, 15 grains.)

SOME ESSENTIAL OILS

Terpene Derivatives

Oil of Lavender. From the flowers of *Lavandula vera*, grown at Mitcham, Surrey. Also an inferior grade from *lavandula spica*, grown in Europe. Contains linalyl acetate, $C_{10}H_{17}.OOC.CH_3$, pinene, $C_{10}H_{16}$, and geraniol, $C_{10}H_{17}.OH$. Sp. gr. about 0.890 at $15^{\circ}C$.

* See Richter's *Organische Chemie*, and Benedikt and Knecht's *Chemistry of Coal-tar Colors*.

Uses: — Perfumes, liquors, ceramic painting and lustres.

Oil of Bergamot. From the greenish-yellow, lemon-shaped fruit of *Citrus bergamia*, grown in Calabria. The skin furnishes the oil which contains dipentene or inactive limonene, $C_{10}H_{16}$; also linanyl acetate, $C_{10}H_{17}.OOC.CH_3$. Sp. gr. about 0.883 at $15^{\circ}C$.

Uses: — Mainly as a perfume.

Oil of Lemon. From the skin of the *Citrus limonum* (lemon). Contains citrene, or right limonene, $C_{10}H_{16}$, and also pinene, $C_{10}H_{16}$. Sp. gr. 0.860 at $15^{\circ}C$.

Uses: — Principally in flavoring.

Oil of Citronella. Prepared from *Andropogon nardus*, a grass grown in India and Ceylon. A yellowish oil containing principally citronellic aldehyde, $C_9H_{17}.CHO$; also borneol, $C_{10}H_{17}.OH$; and geraniol, $C_{10}H_{17}.OH$. Sp. gr. about 0.877 at $16^{\circ}C$. Forms compounds with sodium bisulphite, phenylhydrazine, and reduces ammoniacal silver nitrate ("mirror"). Liable to adulteration with kerosene.

Uses: — Perfume for soap and greases, also for mosquito bite cure and in some liquid "paint removers."

Oil of Lemon-grass. From a grass very similar to that of citronella. The oil is used as a substitute for verbena oil, having a similar odor. Also used in perfumery and in scenting greases.


Phenol Derivatives

Oil of Anise. Mostly anethol. $C_6H_4.C_3H_5.OCH_3$. From the fruit or seeds of *Pimpinella anisum*. Anethol also occurs in fennel seed (*foeniculum vulgare*). May be colorless to dark yellow according to age. Sp. gr. about 0.990 at $15^{\circ}C$. When of good quality, it is characterized by its high solidification point (about $15^{\circ}C$.), and its solubility in an equal weight of 95 per cent alcohol.

Uses: — Used medicinally, increases lactation and relieves flatulency. Also employed in perfumery.

Oil of Cloves. Mainly eugenol. $C_6H_3.C_3H_5.OCH_3.OH$. From a spice tree, *Caryophyllus aromaticus*. Sp. gr. 1.06 at 15° C. Sinks in water.

Uses: — Flavoring, perfumery, and toothache drops.

Oil of Sassafras. Contains safrol. $C_6H_3.C_3H_5$  CH_2 .

From the root of the American sassafras tree. The main constituent, safrol, is also found in the crude Japanese camphor oil (used as a substitute). Sp. gr. about 1.06 or 1.07 at 15° C.

Uses: — Tonic flavor, also for insect bites, and to disguise offensive odors.

Oil of Wintergreen. About 99 per cent methyl salicylate. $C_6H_4.OH.CO.OCH_3$. Naturally in the bark of sweet birch and in the leaves of *Gaultheria procumbens*. Sp. gr. about 1.177 at 15° C. Artificially prepared by passing dry hydrochloric acid gas into a mixture of sodium salicylate and pure methyl alcohol.

Uses: — For flavoring, and perfume; also for rendering substances more palatable. As a remedy for rheumatism, the artificial product is not so efficacious as the natural oil.

Aromatic Aldehydes

Oil of Bitter Almonds. Benzaldehyde. $C_6H_5.CHO$. From "amygdalin," a glucoside found in the fruit of the bitter almond tree, botanically the same as the sweet almond tree but differing in character of fruit. The glucoside by fermentation breaks up into glucose, benzaldehyde, and prussic acid, the latter being the poisonous principle of the *natural* oil. Sp. gr. 1.05 at 15° C. B. P. about 180° C. The *artificial* oil of bitter almonds (ben-

zaldehyde prepared from benzal chloride) is non-poisonous, contains no prussic acid, but it must not be confounded with nitro-benzol, or oil of mirbane (derived from benzol and nitric acid), possessing poisonous properties and similar odor, and used for scenting greases. On exposure to air pure benzaldehyde gradually becomes oxidized to crystalline benzoic acid.

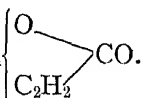
Uses: — Medicinally the true oil of bitter almonds is used as a cough remedy and nerve sedative. Also used in perfumery and, when free from prussic acid, in some liquors.

Oil of Cinnamon (True). Mostly cinnamic aldehyde. $C_6H_5.CH.CH.O$. From the bark of the cinnamon laurel grown in Ceylon. Sp. gr. 1.03 to 1.035 at 15° C. B. P. 240° C. Oil of cassia (Chinese cinnamon) also contains cinnamic aldehyde, some acetate, and eugenol. Liable to adulteration with rosin and petroleum.

Uses: — Perfume and flavoring.

FRAGRANT SUBSTANCES

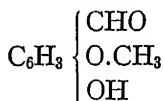
Phenol Derivatives

Cumarin, or Tonka-bean Camphor. C_6H_4 

Fragrant odor of freshly mown grass or hay. Obtained from the bean of the *Dipterix odorata* of Guiana. Artificially prepared by heating salicylic aldehyde with acetic anhydride and anhydrous sodium acetate. White translucent crystals with pleasant vanilla-like odor and burning taste. M. P. 67° C. Distils at 290° C. Soluble in hot water; sparingly, cold. Easily soluble in alcohol, ether, oils, and glycerine.

Uses: — Flavoring and perfume.

Vanilla or Vanillin. Methyl-*proto-catechu* aldehyde.



A substance with pleasant odor, long known to the Mexicans, and derived from the pods of the plant *Vanilla planifolia*. Artificially produced from coniferin through oxidation with chromic acid mixture. (Coniferin is a glucoside, $\text{C}_{16}\text{H}_{22}\text{O}_8 \cdot 2 \text{H}_2\text{O}$, obtained in silky needles from the sap-juice of coniferous plants.) Vanillin is also prepared by oxidation of eugenol (from oil of cloves). Vanillin occurs in white stellated needles or prisms. M. P. 80° to 81°C . Sublimes. B. P. 285°C . Soluble in hot waters; also in alcohol, ether, and chloroform.

Uses: — Flavoring extracts, chocolate, cordials, perfumes.

BALSAMS

Balsams are aromatic exudates composed of the characteristic resin and essential oil of the tree from which derived. The true balsams have oleo-resinous properties, but contain benzoic or cinnamic acids and their esters.

On heating, gum benzoin yields a sublimate of benzoic acid; tolu balsam yields toluol and cinnamic acid; Peru balsam and *Styrax* yield cinnamic esters or derived products.

Exceptions: — Canada balsam and copaiba balsam are turpentine (or terpenes), containing the characteristic resin in solution, and are not regarded as true balsams.

Canada Balsam. Oleo-resinous. Not a true balsam. From Northern United States and Canada. A thick, yellowish, transparent liquid with pine-tree odor. On exposure it forms a hard, transparent film. Contains pinene,

bornyl acetate, resin, etc., and acts as a natural varnish. Soluble in chloroform, ether, petrolic ether, gasoline, turpentine, carbon tetrachloride, and benzol. Imperfectly soluble in absolute alcohol.

Uses: — Cuts and wounds, and microscopical mounts.

Copaiba Balsam. Oleo-resinous. Not a true balsam. From South America (Brazil, Venezuela, and Colombia). Thick, transparent, brownish liquid with bitter nauseating taste. Contains various copaibic acids and essential oil. Soluble in absolute alcohol, ether, petrolic ether, chloroform, and benzol; and in strong alkaline solutions. Alcoholic solution reddens litmus.

Uses: — In pharmacy and medicine as an antiseptic, laxative, and stimulant.

Styrax. (Storax. Oriental sweet gum.) A true balsam. A thick, grayish, sticky, liquid balsam from Asia Minor. When fresh it may appear as an amber-colored liquid. It has a sweet, faint hyacinth odor and sharp, burning taste. Contains styrol (C_8H_8), cinnamic acid ($C_6H_5.C_2H_2.COOH$) styracin (styryl cinnamate, $C_6H_5.C_2H_2.COOC_9H_9$), water and various impurities. Partially soluble (turbid solution) in alcohol, ether, carbon tetrachloride, and benzol. Almost insoluble in petrolic ether.

The ethereal solution, freed from insoluble residue by decantation or filtration and evaporation, yields a thick amber-colored extract of the purified substance.

If the original balsam be distilled with steam, a compound known as styrol ($C_6H_5.CH : C : H_2$) passes over. If the liquid in the still is then made alkaline, the styracin is saponified; and on again distilling with steam, styrene or cinnamic alcohol ($C_6H_5.CH : CH.CH_2OH$) passes over. By filtering the hot residual liquid and treating with hydrochloric acid, cinnamic acid as such ($C_6H_5.CH : CH.COOH$) is obtained.

Uses: — In perfumery to render odor less fugitive; for fumigating pastilles; also for mounting diatoms in microscopical work. In medicine as an antiseptic and expectorant, usually as a tincture.

Balsam Peru. A true balsam from Central America. A dark-brown molasses-like fluid with aromatic sweet odor and faint bitter taste. Contains considerable cinnamoin (benzyl cinnamate, $C_6H_5.C_2H_2.COOC_7H_7$), also styracin, little free cinnamic acid, and resinous matter. Quite soluble in absolute alcohol and benzol. Imperfectly soluble in ether and carbon tetrachloride. Almost insoluble in petroleic ether.

Uses: — Perfumery and chocolate manufacture. In medicine, as an antiseptic and disinfectant for ulcers, scabies, chronic catarrh, etc.

Balsam Tolu. A true balsam from South America (Venezuela and Colombia). Reddish brown, brittle or soft, resinous mass with aromatic odor and taste. Softens in fingers. Contains resinated esters of cinnamic acid; also free cinnamic acid, some benzyl benzoate, styracin, cinnamoin, and vanillin. M. P. 60° to 65° C. Soluble in warm absolute alcohol; partly soluble in ether; quite soluble in mixed alcohol-ether and in hot benzol. Insoluble in hot carbon tetrachloride (unaffected). Insoluble in petroleic ether. Soluble in potash solution.

Uses: — Cough medicine and perfumery; also for fumigating pastilles.

Gum Benzoin. A balsamic exudate or true balsam from styrax benzoin, a tree in the Malay archipelago. Various grades, often dull rusty brown resinous masses with yellowish-white nodules imbedded, friable, and with a faint sweet odor. Contains 12 to 20 per cent free benzoic acid, some vanillin, and resinated esters of benzoic acid, as well as impurities. It melts at 75° C. or above. When heated

it sublimes, giving vapors of benzoic acid. For sublimation, mix powdered gum with an equal volume of sand. Soluble in warm absolute alcohol, excepting impurities. Slightly soluble in ether and carbon tetrachloride. Insoluble in petrolic ether.

Uses: — Perfumery, fumigators, lacquers, etc. As a tincture in cough mixtures. Antiseptic for cuts and wounds, and preservative for ointments and cosmetics.

Remarks: — There are comparatively few characteristic or satisfactory tests on balsams.

The true balsams are generally insoluble in petrolic ether, in distinction from the oleo-resinous terpenes like Canada balsam.

The cinnamic balsams yield the odor of bitter almonds (benzaldehyde) on treating or heating with strong alkaline permanganate or with Labarraque solution. Not so gum benzoin, which imparts a different aromatic odor. The permanganate solution assumes a deep green tint from reduction, changing to black as the reaction becomes more vigorous. The writer prefers alkaline permanganate to a mixture of permanganate and sulphuric acid, since the former produces a bitter almond odor where the acid mixture fails to give more than a charred mass and pungent vapors.

In warm concentrated sulphuric acid:

Balsam tolu dissolves to a clear cherry-red color.

Balsam Peru dissolves to a deep cherry-red color immediately.

Styrax dissolves to a blood-red tint slowly.

Gum benzoin dissolves to a brown, gradually blood-red, color.

On dilution with water the red-colored acid solutions assume a violet tint which is also taken up by the precipitated resinous matter.

Benzoic Acid. $C_6H_5.COOH$. Pearly lustrous plates or needles from gum benzoin by sublimation, or from hip-

puric acid by boiling with concentrated hydrochloric acid, or by oxidation of benzaldehyde, or by conversion of toluene into benzyl chloride and oxidizing the latter. Slightly soluble in cold water. Soluble in hot water. Soluble in alcohol, ether, chloroform, benzol, petrolic ether, amyl alcohol, and oils. M. P. 121° C. Sublimes readily. Volatile with steam. For subliming small quantities, use two close-fitting watch glasses. Place substance in lower glass and over the rim a diaphragm of filter paper; then over this invert the other glass and clamp together. Heat gently on a sand bath, so that vapors pass through filter and condense on upper glass, which is kept cool with a moist pad. For larger quantities use a round dish, and over the edges place a cone of filter paper, on which, after gentle heating, the benzoic acid collects in lustrous needles.* With powdered gum benzoin use an equal volume of sand for sublimation.

Uses: — Antiseptic and antiferment — more powerful than salicylic acid. Also, as a standard for calorimeter tests. Source for sodium benzoate.

TRUE GUMS, GUM RESINS, AND BITUMENS

True Gums. Products of exudation of certain plants. Examples are gum arabic and gum tragacanth, which are uncrystallizable and non-volatile and have slight taste. Chemically, they are little understood. In cold water they dissolve or swell up forming mucilage or jelly (distinction from starch which swells in hot water, and from resins). Insoluble in alcohol (distinction from dextrose, starch, and resins). Do not ferment (distinction from sugars). They are lævorotatory (unlike dextrin). They give no color with iodine, unless starch or dextrin be present.

* Remsen's Organic Chemistry.

Gum Arabic or Gum Acacia. $\text{CaO.C}_{89}\text{H}_{142}\text{O}_{74}$. The calcium salt of arabic acid.* In chemical solutions it interferes with the precipitation of heavy metals, as sulphides; also with certain alkaloidal tests.

Gum Tragacanth. Contains bassorin, $\text{C}_{12}\text{H}_{20}\text{O}_{10}$; also starch and cellulose, as well as some soluble gum. It is hard or "horny," and difficult to pulverize. It expands or swells up when soaked in water, slowly forming a jelly more or less translucent, which possesses slightly cohesive properties as a binding material.

Uses: — Used in calico printing, pastes, pills, and colored crayons; also as an emulsifier and thickening agent.

Pectin. A gummy substance occurring in ripe fruits, and forming the basis for fruit jellies. Inactive to polarized light. Forms main constituent of Irish moss.

Agar-agar. From a variety of seaweed occurring in the Pacific and Indian Oceans, and obtained from Japan and China. It contains pectin and forms a jelly with hot water.

Uses: — Used as a substitute for gelatine, as a sizing for cloth, and as a culture medium for bacteria.

THE RESINS — NOT TRUE GUMS

Gum Copal, Gum Kauri, Gum Damar, etc., are resins, not true gums, belonging to a class of substances in which ordinary rosin is included. The term "resinate" refers to the metallic compounds of rosin, such as "rosin soap" or resinate of soda, resinate of lead and manganese resinate, the latter being well known as a drying agent for paints, oils, and varnishes.

Gum Copal. A fossil resin found on the west coast of Africa — Sierra Leone, Congo, etc. True copals are hard,

* Comm. Org. Anal., 1898, Vol. I, p. 351.

lustrous, yellow, brown, or nearly white, and more or less insoluble in the usual solvents, but are rendered soluble by melting before making into varnish. Sp. gr. about 1.05. M. P. 200° to 250° C.

Manila Copal. From the Philippines. Has different properties from the African copals, being softer and more soluble. Pale brown and pebble-size. Sp. gr. about 1.06. M. P. 110° to 120° C. Not very soluble in alcohol, turpentine, or benzol. Swells in petrolic ether. After melting, it is quite soluble except in alcohol.

Demerara Copal. A fossil resin from British Guiana. Quite lustrous and transparent. Soluble in ether. Swells in alcohol or petrolic ether to a white jelly. Partly soluble in chloroform with swelling.

Gum Damar. From Java, Sumatra, Borneo, etc. A resinous exudate near roots of certain trees. There are different varieties, but the true white occurs in nodules easily broken. Sp. gr. from 1.06 to 1.12. M. P. 120° to 140° C. Soluble in turps, ether and oil; slightly, in alcohol.

Gum Kauri. A fossil resin from New Zealand. Product of a species of pine tree. Similar to copal and found under ground. Also obtained from the living tree in softer, almost colorless pieces. The fossil "gum" is rather dark, brownish, streaky, and opalescent, giving a lustrous conchoidal fracture and an aromatic odor on breaking. Sp. gr. about 1.05. At 200° to 250° C. it melts or fuses, evolves copious fumes, and becomes soluble in ether, turpentine, benzol, amyl alcohol, etc.

Uses:—Much used in varnishes by "running" the melted material in hot linseed oil, thinning, etc.

Shellac. Obtained from resinous incrustation on twigs of certain trees in India. Formed from the sap by an insect, *coccus lacca*, which exudes the lac in which it lays its eggs and in which it becomes embedded. The crude

"stick lac" is rolled and washed to form "seed lac" and, from the washings, a red "lac dye" is obtained.

White shellac is obtained by passing chlorine gas through an alkaline lac solution, whereby the lac is bleached and precipitated. Afterwards, it is melted under water and "pulled" until yellowish white, opaque and brittle.

Orange shellac is formed by melting "seed lac" and straining over cold cylinders of porcelain, wood, or metal, from which, after cooling, it flakes off into brittle, brown, bulky, lustrous, translucent scales. Sp. gr. 1.11 to 1.21. Besides resinous and coloring matter it contains a waxy substance, insoluble in alkaline solutions and alcohol. Orange shellac is easily "cut" by strong wood alcohol and by absolute ethyl alcohol — in fact, more soluble than white shellac, which at times is almost insoluble.* Also soluble in fusel oil and glacial acetic acid. Insoluble in petrolic ether in distinction from rosin.† Soluble in dilute ammonia and in aqueous caustic or carbonated alkali. Dissolves in hot borax solution, the latter, when rubbed up with India ink, forming an excellent marking fluid for laboratory labels, as it is unaffected by acid vapors. (Rosin is slowly soluble in a boiling borax solution.)

Uses of Shellac: — Principally for sealing wax and spirit varnishes, also as a wood "filler."

Amber. A fossil resin found on the shores of the Baltic and sometimes inland by glacial action. Color, reddish brown to transparent yellow; some pieces clear and compact, others streaked with minute air bubbles, or occasionally enclosing an insect. Some pieces float, others sink in

* Rogers and Auberts' Industrial Chemistry.

† A Method of Analyzing Shellac, McIlhiney, Jour. Am. Ch. Soc., 1908, p. 867. For "Shellac Analysis," see Langmuir's method, using glacial acetic acid and Wijs' solution and titrating with N/10 sodium thiosulphate, Jour. Amer. Chem. Soc., 1907, p. 1221; also Jour. Soc. Chem. Ind., 1911, p. 786.

water. Hardest and heaviest of resins. Sp. gr. approximately 1.096. M. P. 120° to 300° C.

Raw Condition: — Unfit for varnish making. Insoluble in alcohol, ether, chloroform, carbon bi-sulphide, benzol, petrolic ether, turpentine, etc.

Heated to Fusion Only: — Advantageous for varnish. Soluble in alcohol, turpentine, oils, etc.

After Melting: — Partial decomposition. Insoluble in alcohol. Soluble in turpentine, hot linseed oil, petrolic ether, chloroform, benzol, etc.

Heated above Melting-point: — Decomposes and gives off fumes of succinic acid and amber oil.

Uses of Amber: — The larger and finer pieces are used for mouthpieces, beads, and combs; the raspings, shavings, and smaller pieces for varnishes. When rubbed it attracts light bodies — hence the word electricity, from the Greek “elektron” meaning amber.

Gum Sandarac. Natural resinous exudate from certain trees in North Africa (Algeria). Yellowish-white, hard, clean, lengthy tears. Sp. gr. 1.03 to 1.04. M. P. 150° C. Soluble in warm alcohol (clear solution) and slowly soluble in acetone. Imperfectly soluble in turpentine, yielding cloudy solution, hot or cold. Hardly soluble in benzol, hot or cold. Insoluble in hot carbon tetrachloride. After fusion, it is soluble in oil.

Uses: — Used for spirit and oil varnishes, incense, etc.

Gum Mastic. From Mediterranean countries (Turkey). A resinous exudate from the lentisk tree. Yellowish, brittle, glassy, rounded drops. Resembles sandarac somewhat, but softens easily in the mouth, and may be chewed or masticated. Solubilities also different. Sp. gr. 1.05 to 1.06. M. P. 105° to 120° C. Incompletely soluble in hot alcohol (cloudy). Imperfectly soluble in acetone (cloudy-white). Quite soluble in hot turpentine (clear

solution). Quite soluble in hot benzol, in hot carbon tetrachloride, also in hot linseed oil.

Uses:—Used for picture varnish, incense, tooth cement, and in Turkey as a chewing-gum.

Common Rosin, or Colophonium. The solid residue obtained from the distillation of turpentine. Color varies from pale amber to dark brown or black. Essentially abietic anhydride, readily hydrolyzed to abietic acid, $C_{44}H_{64}O_6$, but may also contain sylvic acid, $C_{20}H_{30}O_2$.* Sp. gr. 1.04 to 1.1. M. P. 100° to 150° C. Soluble in alcohol, turpentine, ether, acetone, benzol, and in hot linseed oil. The hot alcoholic solution deposits sylvic acid on cooling. Soluble also in hot solutions of caustic or carbonated alkali, the latter producing a froth as CO_2 is liberated, with formation of resinate. Rosin is used as a source for rosin oil and rosin spirit, produced by distillation.

Uses:—Used largely for cheap furniture varnishes, in the “sizing” of paper, in the manufacture of laundry soap, as a flux for solder, and as a coating for casks. A clear solution in wood alcohol makes a cheap spirit varnish, which dries with a more sticky coat than shellac, which is harder. Rosin in alkaline solutions yields a brown coloration due to resinate.

Burgundy Pitch. A resinous exudate from a species of conifers found in France. Yellowish brown lumps, more or less brittle and opaque, with resinous odor. Easily melted. Soluble in glacial acetic acid and in hot alcohol.

Wood Tar. From the destructive distillation of wood in the manufacture of acetic acid. By distilling the tar in iron retorts a light oil and a heavier “creosote oil” are obtained, the residue being used for shoemakers’ wax and axle grease.

* Analyst, 1896, p. 261.

Pine Pitch, or Pine Tar. From the rough distillation of pine wood. Used for tarring rope and oakum.

Caoutchouc, or Rubber Gum (India Rubber). $(C_{10}H_{16})_n$. Obtained from the milky juice of various trees and plants in South America (Para), Borneo, Java, and Madagascar. Composed mainly of a hydrocarbon of the terpene series; nearly white when pure. Specific gravity (when pure) less than water. M. P. 125° C. The commercial product, in balls or cakes, is generally gray or brown from oxidation and impurities, is more or less elastic, and may have a sour, unpleasant odor. It is characterized by its colloidal nature and general insolubility, being insoluble in alcohol and unaffected by dilute acids or alkalis.

The crude or unvulcanized material is slowly and partially soluble (swelling) in carbon bi-sulphide containing 5 per cent absolute alcohol; somewhat in chloroform, acetone, toluol, and petrolic ether. The insoluble portion consists mainly of oxidized hydrocarbon which may vary from 30 to 70 per cent in Para rubber.* Anhydrous pyridin (B. P. 115° to 116° C.) has been recommended as a solvent by MacKensie.† Manufactured rubber‡ may be rendered soluble by treatment with:

(1) Acetone, to remove resins, oils, etc.

(2) Alcoholic potash, to remove oxidized fatty "substitutes."

(3) Cold nitro-benzol, to remove asphalt or pitch.

(4) Boiling nitro-benzol for solution, leaving a residue of mineral matter.

Anilin at from 140° to 180° C. (B. P. 183° C.), has been proposed also as a solvent, the solution being treated with dilute acid to separate the rubber as a tough mass. Hot

* J.S.C.I., 1900, p. 215.

† Jour. Ind. and Eng. Chemistry, 1909, p. 361.

‡ J.S.C.I., 1903, p. 339.

or boiling nitro-benzol (B. P. 205° C.) is one of the best solvents, although (from the writer's experience) the material in solution may become partially blackened or carbonized. The higher the boiling-point of the solvent the quicker its action.

Pure rubber, freshly cut, readily coalesces. It loses elasticity on heating, becomes brittle on chilling, and is destroyed by concentrated acids, chlorine gas, and bromine. Mixed or rolled with sulphur, antimony sulphide, barytes, pigments, "substitutes," etc., it may be made into any shape and afterwards vulcanized by heating, or, by cold immersion in a solution of sulphur chloride and carbon tetrachloride. Vulcanizing increases elasticity and insolubility, but lessens durability and adhesiveness. Little of the sulphur combines chemically, the rest being in admixture. Hard rubber contains an excess of sulphur and "filler," baked at 150° C.

Uses: — Rubber cement, tubing, matting, boots, fabrics, insulation, etc.

Gutta Percha. $(C_{10}H_{16})_n$, $C_{20}H_{32}O$, etc. Closely related to caoutchouc, but from the latex of a different tree in the Malay Archipelago. Less elastic than rubber, and harder. Softens in hot water and melts at about 120° C. Soluble in chloroform, hot toluol, benzol, etc.

Contains a resin "Albane," *soluble* in hot alcohol; also a resin "Fluavile," *soluble* in cold alcohol and in acetone; also "Gutta," precipitated by or insoluble in acetone.*

Uses: — Dental fillings or cements and for insulating material.

Rubber Substitutes. Made from corn oil, linseed oil, and similar vegetable oils by action of sulphur or sulphur chloride, the latter producing a light spongy mass. Somewhat elastic, but friable, and lacking in resiliency.

* J.S.C.I., 1902, pp. 1351, 1368.

Uses:—Used in admixture with gums, pitch, and old rubber.

Gum Chicle. (Balata.) Chewing-gum. From the milky sap of *achras sapota*, a tree in Yucatan. Exported from Mexico. The best grades are nearly white and clean, but, if overheated, a red gum is produced. Consists of an oxidized hydrocarbon, closely related to caoutchouc. Softens in the mouth, and is tasteless but aromatic when heated. Sp. gr. 1.05. Soluble in chloroform, carbon tetrachloride, benzine, and somewhat in alcohol.*

Uses:—Transmission belts, dental surgery, substitute for gutta percha, and more especially for chewing-gum.

BITUMENS

Asphalt. Known to the ancients in Judea and Egypt, but at present obtained mostly from Trinidad. The purer grades are brownish black and lustrous with conchoidal fracture. Sp. gr. about 1.2. M. P. 100° to 150° C. Burns with smoky flame and mild tarry odor. Partly soluble in turpentine ("asphaltene"). Partly soluble in petrolic ether ("petrolene"). Soluble in acetone, benzol, carbon bi-sulphide, and hot linseed oil. Insoluble in alcohol or water, and not attacked by caustic lye, acids, or chlorine.

Uses:—Used for black varnishes, japans, protective coatings for tanks, paving material, paint, insulation, etc.

Coal-tar Pitch. The black residuum from the distillation of tar oil or crude creosote. Contains considerable free carbon with bituminous matter and some anthracene and phenanthrene. Either soft or hard according to extent of distillation. Sp. gr. about 1.3. M. P. about 120° C. Soluble in benzol, carbon bi-sulphide; less so in alcohol. Not so soluble in petrolic ether as asphalt.

Uses:—Used for roofing, pipe coating, paving, etc.

* U. S. Dispensatory; and J.S.C.I., 1902, p. 438, also 1903, p. 1358.

Gilsonite. Lustrous, black, hard, bituminous substance with conchoidal fracture. Found in Utah. Fuses easily in flame of candle. Sp. gr. 1.07. Insoluble in alcohol. Soluble in turpentine.

Uses:—Used for varnishes, brick coatings, insulation, etc.

Albertite. Jet-black bituminous solid from New Brunswick. Slightly fusible with odor. Generally insoluble.

Grahamite. Dull-black solid from West Virginia. Softens and smokes like coking-coal at about 200° C. Insoluble in alcohol. Soluble in turps, chloroform, etc.

CARBOHYDRATES

Cane Sugar. Sucrose. Saccharose. $C_{12}H_{22}O_{11}$. Identical with beet sugar and maple sugar, the taste of the latter being due to agreeable impurities. Cane sugar melted at 160° C. and rapidly cooled forms "barley sugar," an amber-colored solid. Heated to about 215° C. water is expelled and a dark-brown "caramel" remains. Boiled with dilute acids "invert sugar" is produced consisting of equal parts of dextrose and levulose. Soluble in glycerine, dilute alcohol, and aqueous solutions. Inverted by citric acid.* Insoluble in absolute alcohol, ether, chloroform, carbon bi-sulphide, petrolic ether, and turpentine. Does not reduce Fehling's copper solution direct.

Uses:—Universal sweetening agent, and in the form of "caramel" for coloring whiskies.

Invert Sugar. Equal molecular weights of dextrose and levulose produced by action of heat, acids, or diastase on cane sugar; an uncrystallizable syrup having a sweeter taste than cane sugar and existing in fruits, honey, and molasses. Chemically and optically it behaves like a mixture of dextrose and levulose.

* See Milk Sugar.

Dextrose. $C_6H_{12}O_6 \cdot H_2O$. Less sweet than cane sugar. Occurs with levulose in honey and various fruits, as much as 15 per cent in grapes. Crystallizes from aqueous solutions, but anhydrous from hot methyl alcohol. It is an important constituent of "glucose," the amount depending on the method of preparation, as by boiling starch or dextrin with dilute acid, when continued boiling results in the formation of "solid" dextrose or "grape sugar."* May also be obtained from glucosides, as amygdalin, salicin, etc. It reduces Fehling's solution, and rotates plane of polarized light to the right ("dextrorotatory"). Dextrose is soluble in alcohol in distinction from starch and dextrin, which are precipitated (insoluble).

Levulose. Fruit sugar. $C_6H_{12}O_6 \cdot H_2O$. Isomeric with dextrose, with which it occurs in honey and fruits. Obtained from cane sugar by "inversion" — but not from glucosides. Its aqueous solution is slightly sweeter than the same strength solution of cane sugar and much sweeter than one of dextrose. Very soluble in water, and crystallizes from alcohol in the anhydrous form. It reduces Fehling's solution, and rotates the plane of polarized light very strongly to the left; hence, the name, levulose, from "laevorotatory" properties.

Commercial Glucose. Starch sugar. Constituents: dextrose, maltose, and dextrin. Two forms: syrupy or liquid, and the solid anhydrous glucose known as "grape sugar." Produced by the action of dilute acid on potato, rice, or corn starch. The true glucose syrup is not very sweet, almost tasteless, slightly yellowish, and viscous.

Uses: — Confectionery, table syrups, and artificial honey; also as a brewer's malt substitute, and as a "body" for certain natural dyewood extracts, such as logwood and tannin. Has also been employed in the reduction of

* Thorp, Ind. Chem., 1899, p. 365.

indigo to the soluble "indigo-white," from which the indigo can be reproduced by oxidation.

Molasses. The molasses from raw sugar usually contains a large amount of invert sugar. Molasses from beet sugar is comparatively free from "invert," but contains raffinose. Refined syrup may contain about 35 per cent of sucrose. Sorghum molasses, well-known in the western part of the United States, possesses a somewhat different taste, perhaps not so palatable as the cane-sugar molasses.

Raffinose. $C_6H_{14}O_7$. From beets. Not fermentable. Has a high rotation. Does not reduce Fehling's solution.

Malt. (See maltose.) This is barley which has been steeped and allowed to germinate, the "starchy" material being converted into maltose, or "malt sugar," and dextrin through the action of the diastase ferment naturally present. The action of the ferment is checked at the proper stage by kiln-drying.

Maltose. $C_{12}H_{22}O_{11} \cdot H_2O$. The action of diastase on malt, maize, or rice produces maltose and dextrin, but not dextrose or other form of glucose. Maltose, by itself, may be converted into dextrose by heating with dilute acid; or into dextrose and alcohol by yeast fermentation. When a mixture of maltose and dextrin is fermented together with yeast, the dextrose disappears before the maltose is attacked.* Maltose reduces Fehling's solution, but not to the same extent as dextrose. Heated with dilute acid it is slowly converted into dextrose, the action being slower than in the case of cane sugar. Maltose is less soluble in alcohol than cane sugar. An "impure maltose" is produced by the action of a "malt infusion" on starch.

Milk Sugar. Lactose. $C_{12}H_{22}O_{11} \cdot H_2O$. Isomeric with maltose. Dextrorotatory. By "hydrolysis," or boiling with dilute mineral acid, it gives galactose and sucro-

* Allen, Vol. I, 1898, p. 265.

dextrose, both of which are dextro-glucoses, the rotation thereby being increased. Unlike sucrose, it is not inverted by citric acid. Milk sugar occurs in human as well as cow's milk, and in the milk of other mammals (goat, elephant, dog, mare, porpoise, etc.). It is less sweet than cane sugar, and also less soluble in water (in six parts cold water). Insoluble in alcohol or ether. Reduces Fehling's solution readily on heating (distinction from sucrose), but does not reduce Barfoed's cupric acetate reagent (distinction from glucose). Rapidly reduces ammoniacal silver nitrate, hence employed in silvering glass.

Starch. $(C_6H_{10}O_5)_n$. A polysaccharide. Obtained from potatoes, corn, wheat, rice, arrowroot, sago, etc. Separated from gluten and fatty matters by first softening with water, then crushing, treating with alkali, settling (levigation), draining by centrifugal, etc. Insoluble in cold water, alcohol, or ether. Heated with water to $80^\circ C.$, the granules swell or burst, yielding a gelatinous solution, which forms a dark blue body or color with free iodine — not a definite compound but known as “iodized starch,” much used as an “indicator” in volumetric analysis. The pasty starch solution deteriorates on standing, forming “erythro-dextrin” which gives a violet or reddish-brown color with iodine. On long exposure to the air, lactic acid is formed.* A solution of caustic potash (3 per cent strength) causes starch to swell in the cold to a paste. “Soluble starch” may be formed by triturating starch with two-thirds its weight of cold concentrated sulphuric acid and, after a time, washing and filtering with alcohol to remove the acid. In this form it is soluble in cold water, forming a syrupy liquid or colloidal paste which is colored blue with iodine.†

* Allen, Vol. I, p. 332.

† See Prescott's Proximate Organic Analysis, 1893, p. 164; also Rogers and Aubert's Industrial Chemistry.

Starch solutions are precipitated by 50 per cent alcohol; also by tannin and baryta water (distinction from dextrin). Lead sub-acetate precipitates both starch and dextrin. Starch may be separated from gelatine and albumen by transforming the starch to glucose and washing out the latter with 90 per cent alcohol. It is easily transformed to glucose by boiling with dilute mineral acid. Converted by diastase ferment or by saliva into maltose and dextrin (means of distinction from gum arabic and other gummy substances).

Uses: — Corn starch is used for both food and laundry work as well as for making glucose. Potato starch is much used in Europe. Wheat starch, independently of its food value, makes one of the best adhesives. Tapioca is derived from cassava starch. Rice and arrowroot starch are much used for sizing and toilet powders.

Dextrin. $(C_6H_{10}O_5)_n$. Amorphous white or yellowish powder or lumps. The commercial form, "British Gum," may be made by moistening starch or flour with dilute nitric acid, slowly drying the paste, then heating for some time at 100° – 125° C., until it acquires a brown or yellow color. Dextrin is also produced in the manufacture of glucose and in the fermentation of malt. It is strongly dextrorotatory. Soluble in cold water and in very dilute alcohol. Insoluble in absolute alcohol, which precipitates it from aqueous solutions. Insoluble in ether. Distinguished from starch and "soluble starch" by giving no blue color with iodine and no precipitate with tannic acid or baryta water. "Erythro-dextrin" occurring largely in the commercial dextrin gives a reddish brown coloration with iodine (as in the case of old starch solutions). Dextrin does not reduce Fehling's solution direct nor Barfoed's cupric acetate reagent (distinction from glucose). Boiled with dilute mineral acids, it is converted into glucose, which

reduces Fehling's solution. Distinguished from albumen by non-coagulation with heat and non-precipitation with tannin.

Uses: — Used largely for gumming postage stamps and for library pastes; as a substitute for gum arabic and in the printing of fabrics.

Cellulose. $C_6H_{10}O_5$. Cellular tissue of plants, the main constituent of cotton, linen, wood-pulp, filter paper, etc., and closely related to starch. White, tasteless, and odorless. Sp. gr. 1.5. Insoluble in water and ordinary solvents. Soluble in an ammoniacal solution of cupric oxide (Schweitzer's reagent) prepared by precipitating a solution of copper sulphate with caustic soda, then washing the precipitate thoroughly and dissolving in the least amount of concentrated ammonia, yielding a blue solution. For raw cotton, first treat with concentrated caustic soda until fibres swell and become translucent, then press out liquid and apply reagent to the "mercerized" cotton. Wood-pulp ground with solid caustic soda forms alkali-cellulose which, on treatment with carbon bi-sulphide, yields cellulose xanthate soluble in water to a viscous solution "viscose."* Cellulose is dissolved by concentrated sulphuric acid to a viscous solution, which, on dilution with water, forms an amorphous body, amyloid. (Basis of vegetable parchment from unsized paper.) Digested with a concentrated zinc chloride solution, cellulose dissolves to a syrupy liquid which, by passing through small orifices into alcohol, may be precipitated as a thread. (Basis of carbon filaments for incandescent lamps.) Heated with acetic anhydride at 180° C. in a closed tube, cellulose forms the tri-acetate. Iodine alone gives no coloration with cellulose; but, in conjunction with concentrated sulphuric acid, a solution of iodine in potassium iodide gives a blue color.

* Matthews' Textile Fibres, 1907, p. 263.

(Due to amyloid.) Boiled with strong nitric acid, cellulose is oxidized to oxy-cellulose and oxalic acid; but, in presence of concentrated sulphuric acid, the action is wholly different, various nitrated products or pyroxylin being produced.

Pyroxylin. Soluble guncotton. A mixture of tetra- and penta-nitrates of cellulose, $C_{12}H_{16}O_6(O.NO_2)_4$ and $C_{12}H_{15}O_5(O.NO_2)_5$. Prepared by dipping cotton in a warm mixture of saltpeter (2 parts) and concentrated sulphuric acid (3 parts), washing, drying, etc.* Soluble in a mixture of ether and alcohol, forming the so-called "collodion" used in photography.

Uses:—Its solubility in a mixture of methyl alcohol, amyl alcohol, and amyl acetate forms the basis for manufacture of photographic films, celluloid varnishes, bronzing liquids, lacquers, and "liquid skin" preparations for cuts and wounds. Also used in "smokeless powders." Its solution in brom-nitro-toluol is stated to give an elastic body resembling India rubber. Dissolved in molten camphor, it forms celluloid.

Guncotton. (Insoluble.) Cellulose hexa-nitrate, $C_{12}H_{14}O_4(O.NO_2)_6$. Insoluble in alcohol and ether; swells in nitro-benzol. Prepared in a cold mixture of nitric and sulphuric acids. Explodes by detonation and spontaneous decomposition.

FEHLING'S SUGAR-TEST SOLUTION

Fehling's solution is a mixture of two solutions: equal volumes of copper sulphate and alkaline tartrate solutions.† On mixing, a light-blue precipitate is formed, which quickly dissolves to a dark-blue liquid. The solutions are kept in separate bottles.

* Richter's Organische Chemie.

† Allen's Chemistry of Urine, 1895, p. 59.

No. 1.—Copper sulphate ($\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$) . . . 34.64 grams.
Dissolve by heat in 200 c.c. distilled water, filter, cool and make up to 500 c.c.

No. 2.—Rochelle salt (potassium sodium tartrate) 180 grams.
Dissolve in 300 c.c. hot distilled water and filter. Add 100 grams C. P. caustic potash (or 70 grams caustic soda). Cool and make up to 500 c.c.

For use mix 5 c.c. each, Nos. 1 and 2, in a large test-tube or casserole, so that a 10 c.c. mixture is equivalent to 0.05 gram glucose, 0.0475 gram cane sugar (by inversion), 0.0678 gram lactose, 0.045 gram starch (by inversion), or 0.082 gram maltose.

Dilute with 40 c.c. water, boil, and add sugar solution drop by drop until all copper is precipitated as red Cu_2O .

End Reaction:—Clear supernatant liquid should no longer give a brown color with ferricyanide and acetic acid indicator.

Reduced by invert sugar, dextrose, levulose, maltose, milk sugar, chloroform, chloral, acetaldehyde, salicylic acid, uric acid, xanthine, creatinine, etc.

Not reduced by cane sugar (direct), raffinose, dextrin, or cellulose; nor by alcohol, glycerin, phenol, benzaldehyde, urea, saccharin, or acetic, lactic, oxalic, and sulphurous acids; nor by starch (direct).

Interfering agents, as albumen, creatinine, xanthine, uric acid, coloring matter, etc., should be removed beforehand by the cupric acetate modification of Fehling's method proposed by Allen.

Impurities may also be removed by adding little dry lead

acetate, transposing excess lead with measured quantity of the Fehling copper-sulphate solution, forming cupric acetate and insoluble lead sulphate, filtering, washing, and adding equivalent alkaline tartrate solution, when, on heating, a brilliant red reduction should occur in presence of reducing sugar. Cane sugar (sucrose) must be inverted beforehand by boiling a few minutes with a few drops of concentrated hydrochloric acid, then neutralizing, etc. Likewise with starch.

PAVY'S AMMONIACAL SUGAR-TEST SOLUTION

This solution is one-tenth the strength of Fehling's, from which it may be prepared by mixing:

120 c.c. Fehling's solution.

300 c.c. concentrated ammonia (sp. gr. 0.9).

100 c.c. 10 per cent caustic potash solution.

Make up with distilled water to 1000 c.c.

Of this, 100 c.c. is equivalent to 0.050 gram glucose, and 10 c.c. is equivalent to 0.005 gram glucose.

Pavy's reagent is simply decolorized on heating with a glucose solution, without precipitation of cuprous oxide.

The ratio of reduction represented by the Fehling and Pavy reactions is 6 : 5 CuO , due to influence of fixed alkali and ammonia; hence, 120 c.c. Fehling's (instead of 100 c.c.) is employed to obtain an equivalent for Pavy's solution.

After reduction to colorless condition, it gradually oxidizes to original blue on exposure to air. For accuracy, the air should be excluded during the test, using a small flask connected with a burette by means of tubing and rubber stopper and provided with back pressure and exit tubes, the latter dipping into water.

Adapted for testing diabetic urine and impure saccharine

liquids, especially after clarifying with mercury bi-chloride and removing excess mercury by boiling with zinc dust.

BARFOED'S CUPRIC ACETATE TEST FOR GLUCOSE

Useful as a qualitative test for distinguishing glucose from milk sugar and maltose.

Dissolve 9 grams crystallized copper acetate in 180 c.c. distilled water, add 0.2 c.c. (4 drops) 50 per cent acetic acid, and make up to 200 c.c. Place 5 c.c. reagent and 5 c.c. solution to be tested in a test-tube, and heat in a water-bath $3\frac{1}{2}$ minutes. Note any reduction color against a black background. Sensitive to $\frac{2}{100}$ per cent dextrose and $\frac{2}{10}$ per cent maltose. Dextrin, cane sugar, and milk sugar give no reduction except on hydrolysis from prolonged heating.

Proteids, if present, are precipitated rendering test less sensitive.*

ALBUMENOIDS OR PROTEIDS

These are nitrogenous bodies occurring in both the animal and vegetable kingdoms. All proteids contain similar proportions of carbon, hydrogen, nitrogen, and oxygen, with some sulphur. Hæmoglobin and hæmatëin have iron besides sulphur. Nuclein and casein have phosphorus besides sulphur. Turacin (red feathers of turaco) contains copper. Gelatine differs from proteids in containing little or no sulphur.†

Animal Albumenoids. Common examples are blood albumen, egg albumen, casein, etc., which are generally soluble in water, especially if slightly alkaline. Egg albumen is soluble in cold water, but is coagulated and precipitated on heating and by metallic salts. It is insoluble

* Consult Sherman's Organic Analysis.

† Allen, Vol. IV, 1898, p. 14.

in alcohol. Casein, naturally present in milk, is coagulated by "rennet," but not by boiling (distinction from milk albumen which is coagulated by boiling but not by "rennet"). In milk, the casein exists apparently in suspension as if emulsified; and, although insoluble itself in pure water, it becomes soluble in presence of alkali and strong acids.

Vegetable Albumenoids. These occur in both soluble and insoluble forms, prominent in composition of cereals. Gluten is an insoluble form present in wheat flour, less in barley or rye. Soluble vegetable albumen is coagulated by heat. Cerealin is a soluble nitrogenous "ferment" present in wheat bran, converting starch into dextrin and thus acting like a malt extract. Hence, bran is objectionable in flour.

Dried Casein. A proteid, obtained from cow's milk by removing fat, precipitating curd with dilute mineral acid, washing, drying, etc. A whitish or yellowish substance which swells in hot water without dissolving. It is soluble in weak alkaline solutions, as dilute ammonia or lime water. Soluble in strong acetic acid. Soluble in dilute acids, as $\frac{1}{10}$ of 1 per cent HCl, but is *insoluble* in 1 per cent HCl.* It is quite soluble in concentrated HCl with violet coloration. Insoluble in alcohol or ether. A dilute alkaline solution of casein, when boiled, forms a "scum" as in the case of milk. An alkaline solution of casein mixed with formaldehyde yields, on evaporation, a thin translucent film impervious to water.

Uses: — A mixture of casein and slaked lime has been employed as an earthenware cement; sets hard and is insoluble, well adapted for filling cracks.

On account of its general impervious and adhesive properties, casein has to some extent been employed as

* Allen, Vol. IV, 1898, p. 100.

a paint vehicle and substitute for shellac. It may be superior to shellac as a protective and moisture-proof coating; but, like other nitrogenous animal substances, the aqueous mixture is liable to putrefy unless precautions are taken to prevent putrefaction by adding some agent, as formaldehyde, which would not only act as a preservative but would also render the coating harder and more impervious to moisture. A 5 per cent solution of casein in dilute ammonia water (1 : 12) — dissolved at 70° C. — gives a varnish mixture. The casein coating has a rough surface, which may be improved somewhat by adding a little glycerine and yolk of egg to the mixture as well as formalin. Casein has also been employed as a substitute for horn and rubber in the manufacture of buttons.

Gluten. A mixed vegetable proteid from wheat, containing glutenin and gliadin.* Insoluble in cold water; partially soluble in boiling water and alcohol. Glutenin is soluble in boiling alcohol (0.890 gr.). Gliadin is insoluble in absolute alcohol, but quite soluble in 70 per cent alcohol.† Soluble salts assist in the formation of gluten. The gliadin imparts sticky binding properties, while the glutenin gives solidity. One part gliadin mixed with 10 parts starch forms a soluble dough, but no gluten.‡

Gluten is extracted from wheat flour by moistening the flour with cold water, kneading into a dough, placing between folds of cloth, and washing out starch in a stream of water, thereby leaving a sticky plastic mass very rich in nitrogen. The operation may, perhaps, be more easily performed in a cloth (muslin) bag, fastening the edges of the bag over a faucet, and allowing a stream of water to percolate through the flour in the bag, leaving the gluten

* Comm. Org. Anal., 1898, Vol. IV, p. 82.

† Ibid., pp. 79, 81.

‡ Ibid., p. 82.

behind as a sticky residue. For moist determination,* 10 grams of sample in a porcelain dish is moistened with 6 or 7 c.c. cold water, kneaded into a ball without sticking to the dish, and allowed to stand one hour. Then, with the mass in hand, knead in a stream of water until starch and soluble matter are washed out. Place in cold water one hour, then remove and press between the hands until dry as possible; roll into a ball and weigh. For dry gluten place the weighed ball of moist gluten in an oven at the temperature of boiling water for 21 hours. After cooling, weigh.

PROTEOIDS, OR COLLAGENS

Gelatine. $C_{102}H_{161}N_{31}O_{39}$. An example differing from the proteids in that it contains little or no sulphur. Obtained by boiling hoofs, tendons, etc., of animals. Swells in cold water on standing. Soluble in hot water, forming a jelly on cooling. Soluble in warm concentrated acetic acid forming a strongly adhesive paste. Solutions of gelatine are "colloidal," that is, non-crystallizable and of low diffusion power and may be freed from salts by dialysis through parchment. Gelatine is insoluble in alcohol, ether, chloroform, benzol, oils, etc. Potassium bichromate renders aqueous gelatine insoluble on exposure to light, a fact utilized in photomechanical processes. Potassium ferro- or ferricyanide does not precipitate gelatine from its solution (distinction from albumen). Tannin precipitates gelatine from its solution in water and vice-versa, one serving to detect the other. Formalin added to a warm concentrated solution of gelatine, stirred, evaporated, etc., produces formogelatine which is quite insoluble in hot water.

Isinglass. (Fish gluc.) Prepared from the swimming bladders of fish. It is a pure collagen — white, translu-

* Bulletin No. 45, U. S. Dep't of Agriculture, Analysis of Cereals, p. 10.

cent, and fibrous — and has the property of swelling up in cold water. It is employed as a clarifying agent for wines, beers, and other liquids. Transformed into gelatine by heating with water.

Glue. Glue is practically an impure gelatine, possessing similar properties and solubilities.

N.B. — Agar-agar from a variety of seaweed is a gelatine substitute, having similar physical properties but containing very little nitrogen. It contains gelose, $(C_6H_{10}O_5)_x$?, with some pectin, and has a greater gelatinizing power than isinglass.

OILS, FATS, AND WAXES

Saponifiable Material (as “compound ethers”). Glycerides, containing “glyceryl radicle,” such as butter fat, lard tallow, linseed oil, Japan wax, etc. Non-glycerides, containing other alkyl groups, as spermaceti, sperm oil, beeswax, Chinese wax, oil of wintergreen (methyl salicylate), etc.

Non-saponifiable Material (no soap formed). Petroleum compounds, such as mineral oils, paraffin, ceresin, ozocerite, vaseline, kerosene, etc.

Alcoholic bodies, as cholesterol and phytosterol, and oil of geranium (geraniol), $C_{10}H_{17}OH$.

Aldehydes, as oil of bitter almonds (benzaldehyde), $C_6H_5.CHO$, and oil of cinnamon (cinnamic aldehyde), $C_6H_5.C_2H_2.CHO$.

Phenol derivatives, such as tar oils, also oil of anise (anethol), and oil of sassafras (safrol).

Camphors, as oil of peppermint; and terpenes, as oil of turpentine, cloves, lemon, lavender, bergamot, etc.

Saponification. The quantity of caustic potash required for the saponification of most oils and fats averages about 20 per cent of the weight of the sample, with the excep-

tion of castor (17.8 per cent), rape (17.5 per cent), and sperm (13.5 per cent). Mineral oil has no saponification figure. Lard, tallow, stearin, olein, palmitin, olive oil, corn oil, cottonseed oil, sweet almond oil, cacao butter, etc., all these have practically the same saponification figure, varying from 19 per cent to 20 per cent. Therefore, the weight of caustic potash required, multiplied by five, approximates the weight of the oil or fat which has been saponified. The soap formed is a salt of the characteristic fatty acid.

Glycerides. These are fatty compounds containing a "glyceryl" radicle, the name being applied to those fats and oils which yield glycerol on saponification, such as:

Tri-butylin in butter.

Tri-olein in olive and almond oils.

Tri-stearin in tallow, lard, and cacao butter.

Tri-palmitin in palm oil and lard.

Tri-linolin in linseed oil.

Tri-ricinolin in castor oil.

Tri-laurin and tri-palmitin in Japan wax (not a true wax).

Non-glycerides. Under this name are included those fats and waxes which do not yield glycerol on saponification as:

Cetyl palmitate in spermaceti.

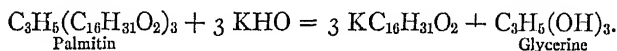
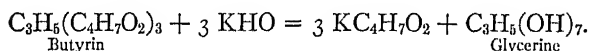
Ceryl cerotate in Chinese wax.

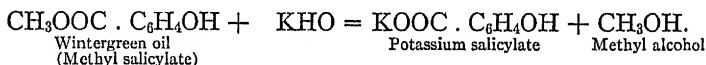
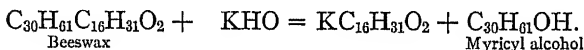
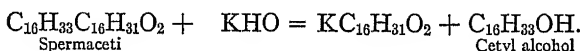
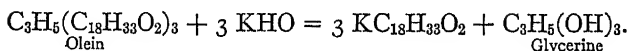
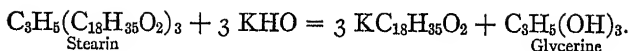
Myricyl cerotate in carnauba wax.

Myricyl palmitate in beeswax.

Do-decatyl oleate in sperm oil (a liquid wax).

SAPONIFICATION REACTIONS





The saponification test not only serves for the detection of fatty oil in presence of mineral oil, but, in conjunction with other tests, affords a means of identification and estimation of purity owing to different molecular weights of the fatty acids involved. The following exhibit differences.

Castor oil.....	17.8% KHO.
Rape oil.....	17.5% KHO.
Sperm oil.....	13.5% KHO.
Spermaceti.....	12.7% to 13% KHO.
Tallow.....	19.3% to 19.8% KHO.
Beeswax.....	9.2% to 9.7% KHO.
Japan wax.....	21.0% to 22.2% KHO.
Linseed oil.....	18.74% to 19.52% KHO.

THE KOETTSTORFER PROCESS

The Koettstorfer figure, or saponification number, is the number of milligrams of caustic potash (KHO) required to saponify one gram of the oil, fat, or wax; that is, to neutralize the total fatty acids, free or combined, derived from one gram of the substance. The per cent KHO is $\frac{1}{100}$ the Koettstorfer figure.

The "saponification equivalent" (proposed by Allen) represents the number of grams of oil or fat saponified

by 56.158 grams of caustic potash or by the molecular equivalent in grams of any alkali. It may be derived by dividing 56158 (the number of milligrams KHO in one litre normal solution) by the Koettstorfer figure. In the case of triglycerides the "saponification equivalent" is one-third the mean molecular weight of the glycerides as such.

The "saponification equivalent" increases as the Koettstorfer or saponification number decreases.

Method: — Use two Erlenmeyer flasks (250 c.c. each); one for sample, the other for control. Weigh about 5 grams fat or oil in one flask, add 50 c.c. alcoholic potash (made by dissolving 20 grams C. P. caustic potash in 500 c.c. alcohol, previously purified from aldehyde by treatment with permanganate and distillation over CaCO_3 , and using a clear solution only), connect with reflux condenser, and boil thirty minutes, or until saponification is clear. At the same time run a blank test on 50 c.c. alcoholic potash alone. Cool the flasks, add phenol-phthalein indicator, and titrate each with $\text{N}/2$ hydrochloric acid. The difference between the number c.c. acid required for sample and that required for blank represents an equivalent in acid for the alkali consumed in saponification, thus: 1 c.c. $\text{N}/2$ HCl contains 0.01823 gram HCl, equivalent to 0.02808 gram KHO, which, multiplied by difference in cubic centimeters $\text{N}/2$ acid, gives the weight of KHO consumed from which the per cent caustic potash and the Koettstorfer figure may be determined.

ACID NUMBER AND ESTER NUMBER

The "acid number" represents the number of milligrams of caustic potash required to neutralize the free fatty acids in one gram of the sample. The "Ester number" represents the difference between the Koettstorfer figure and the "acid number."

To determine the "acid number," first neutralize a quantity of 95 per cent alcohol with dry sodium carbonate (insoluble in alcohol) until faintly pink to phenol-phthalein; then filter and reserve. For the test, shake 5 grams of the oil or fat with 50 c.c. neutralized alcohol, and heat to boiling one minute. Any acidity discharges the pink color immediately. The warm alcohol takes up the free fatty acid, which may be titrated with N/10 alkali and calculated to oleic or stearic acid, as the case may be.

REICHERT DISTILLATION PROCESS FOR VOLATILE FATTY ACIDS

An arbitrary method for determining the volatile fatty acids in various oils or fats, such as butter fat.

The operation should be performed on a sample of the clear fat or oil. Weigh exactly 2.5 grams of this fat or oil in a 200 c.c. Erlenmeyer flask (containing a platinum spiral to prevent "bumping" during heating) and saponify with 20 c.c. 70 per cent alcohol containing 1 gram KHO. Evaporate all alcohol, using suction if possible.

Dissolve with 50 c.c. water, and add 20 c.c. dilute H_2SO_4 to liberate fatty acids.

Distil through filter until 50 c.c. have passed over; then titrate with N/10 alkali, using phenol-phthalein as indicator.

The Reichert figure signifies the number of cubic centimeters of N/10 alkali to neutralize the first 50 c.c. distillate.

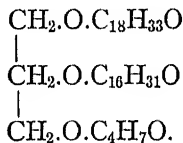
Butter fat requires	11.5 to 15.0 c.c. N/10 alkali
Oleomargarine requires . . .	0.2 to 0.5 c.c. N/10 alkali
Cocoanut oil requires	3.0 to 5.0 c.c. N/10 alkali

If necessary, the distillation may be carried further by adding water and distilling 50 c.c. each time. Titrate each

50 c.c. until no more acidity, and calculate to butyric acid.

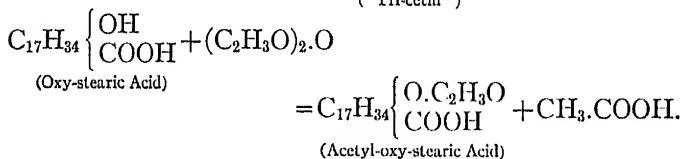
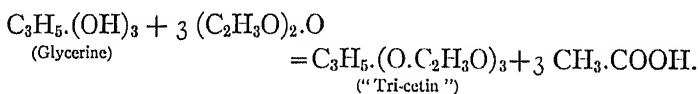
The *insoluble* fatty acids remain behind and may be weighed in the same flask as the original sample, thus: *wash* with hot water; *chill*, and pour off aqueous solution; *dry* in hot-air bath, cool, and weigh.

Butter fat seems to be a mixed glyceride as: *oleo palmito butyric glyceride*.*



No butyrine can be dissolved out by alcohol, although butyric acid may be obtained by saponification.

Acetylization. Organic or fatty substances with alkyl hydroxyl groups, as alcohol, glycerine, castor oil, waxes, etc., when heated with acetic anhydride, form "acetylated" products, thus:



Use a round bottom flask and reflux condenser.

Ten grams of sample fat, wax, oil, or glycerol are "acetylized" direct by boiling with 20 grams acetic anhydride for two hours.

* See Oils, Fats, Waxes, etc., Alder Wright, 1894, p. 9.

The mixture is then poured into 500 c.c. hot water, in a large beaker, and boiled thirty minutes, passing a current of CO_2 to prevent bumping. Allow to separate into two layers, and siphon off aqueous portion.

Repeat treatment, boiling the oily layer with fresh water three times in succession to remove last traces of acetic acid and testing the last portion with litmus. The "acetylated" material is freed from water and filtered through a dry filter paper in a drying-oven.

Saponify 2.5 grams of the "acetylated" product with a known amount of standard alcoholic caustic potash (tested by blank).

Evaporate almost to dryness, take up with water, and add an amount of standard H_2SO_4 exactly equivalent to KOH used for saponification.

Warm gently until fatty acids separate, filter through wet filter, wash with hot water until washings are neutral, and titrate combined filtrate and washings (containing liberated acetic acid and soluble fatty acids) with $\text{N}/10$ KOH, using phenol-phthalein as indicator. Deduct alkali required for any soluble fatty acids in original substance (Reichert distillation). Calculate the "acetyl number," which is the number of milligrams KOH required to neutralize acetic acid liberated from one gram "acetylated" fat or wax.

Remarks: — In the original method of Benedikt and Ulzer the sample was first saponified, and only the insoluble fatty acids were taken for acetylation. No account, evidently, was taken of the soluble or volatile fatty acids.

Various discrepancies in the acetyl number were observed which, according to Lewkowitsch, might result from formation of fatty anhydrides, as lauric, palmitic, or stearic (independently of the acetylated hydroxy fatty acids) in the presence of an excess of acetic anhydride.

These fatty anhydrides remained unaffected by water treatment, but, subsequently, on neutralizing and saponifying with excess of alcoholic potash and back-titrating, a quantity of alkali was consumed equivalent to fatty acids formed through hydrolysis of the fatty anhydrides.

Therefore, Lewkowitsch proposed a modified method similar to that already described, viz., direct acetylation of the original substance.*

In the examination of unsaponifiable matter from fats and oils, as well as certain waxes, the acetylation test may be used for estimating the amount of higher alcoholic bodies or hydroxy substances by conversion into compound ethers, as cholesterol and phytosterol acetates and also cetyl and myricyl acetates, whereby the identification of a particular oil or wax, and its percentage in admixture, is rendered possible.

For the analysis of glycerine Langmuir proposes the "Acetin Method," using 1.25 to 1.5 grams glycerine, 3 grams anhydrous sodium acetate, and 7.5 c.c. C. P. acetic anhydride, heated in a 120-c.c. flask with upright Liebig condenser. The product, after filtering, washing, and neutralizing in the cold, is boiled with known excess of $N/1$ NaOH, cooled, and back-titrated with $N/1$ HCl; and the glycerol calculated from alkali consumed. Allowances are made for acetylatable impurities by treatment in a similar manner of the total residue obtained at 160° C.†

Iodine Absorption. (Hübl Method.) The Hübl figure represents the number of grams of iodine absorbed by 100 grams of the oil or fat.

This is a useful test for many oils, as linseed, cotton-

* Alder Wright, *Oils, Fats, Waxes, etc.*, 1894, pp. 189-190; also Lewkowitsch's *Oils, Fats, and Waxes*, 1909; J.S.C.I., 1897, p. 503; 1900, p. 74.

† Jour. Ind. & Eng. Chem., 1911, p. 679.

seed, olive, etc., based on the fact that certain fatty oils, containing unsaturated carbon groups, have the property of absorbing halogens like iodine or bromine in proportion to the number of free "bonds," thereby becoming "saturated."

Oleic acid takes up 2 atoms iodine.

Ricinoleic acid takes up 2 atoms iodine.

Linolic acid takes up 4 atoms iodine.

Linolenic acid takes up 6 atoms iodine.

For analysis it is customary to take:

Drying oils	0.2 to 0.4 gm.
Non-drying oils	0.3 to 0.4 gm.
Fats	0.8 to 1.0 gm.

Solutions required:

No. 1. Iodo-mercuric.

(a) 25 grams iodine in 500 c.c. 95% alcohol.

(b) 30 grams HgCl_2 in 500 c.c. 95% alcohol.

To be mixed in equal portions — as 100 c.c. each (a) and (b) — 24 hours before using.

No. 2. $\text{N}/10 \text{ Na}_2\text{S}_2\text{O}_3 \cdot 5 \text{ H}_2\text{O}$ ("hypo" 24.8 grams per L.).

No. 3. $\frac{1}{60} \text{ K}_2\text{Cr}_2\text{O}_7$ ($\text{N}/10$ oxidizing ratio) for standardizing the No. 2. sodium thiosulphate solution.

No. 4. 20 per cent potassium iodide solution.

No. 5. Boiled starch "indicator" solution.

No. 6. C. P. conc. H_2SO_4 .

As to standardizing the "hypo" with bichromate, $\frac{1}{60}$ the molecular weight of $\text{K}_2\text{Cr}_2\text{O}_7$ is equivalent to $\text{N}/10$ based on its oxidizing value. That is: 1 $\text{K}_2\text{Cr}_2\text{O}_7$ liberates 3 I_2 , and 3 I_2 oxidizes 6 $\text{Na}_2\text{S}_2\text{O}_3$, therefore $\frac{1}{60} \text{ K}_2\text{Cr}_2\text{O}_7$ is equivalent to $\text{N}/\text{Na}_2\text{S}_2\text{O}_3 \cdot 5 \text{ H}_2\text{O}$, and 1 c.c. $\frac{1}{60} \text{ K}_2\text{Cr}_2\text{O}_7$ equals 1 c.c. $\text{N}/10 \text{ Na}_2\text{S}_2\text{O}_3 \cdot 5 \text{ H}_2\text{O}$, and 1 c.c. $\frac{1}{60} \text{ K}_2\text{Cr}_2\text{O}_7$ equals 1 c.c. $\text{N}/10$ iodine.

The molecular weight of $K_2Cr_2O_7$ is 294.8, therefore each c.c. of its $\frac{1}{10}$ solution should contain 0.0049 gram of the bichromate, equivalent to 0.01265 gram iodine, and this in turn is likewise equivalent to 0.02480 gram "hypo."

Standardize the "hypo" by running a measured quantity of the $\frac{1}{10}$ bichromate from the burette into a glass-stoppered flask, adding a sufficient excess of KI solution, then a little concentrated H_2SO_4 to liberate iodine. Allow the red solution to mix (slightly warm from acid added), then titrate with the standard "hypo" until color is nearly discharged or yellow.

A few drops of the starch solution are then added, producing a grayish blue or slaty color from "starch iodide," which acts as an "indicator," the bluish color being completely discharged on adding the last few drops of "hypo," thereby completing the "end reaction."

Reaction: — $K_2Cr_2O_7 + 6 KI + 7 H_2SO_4 = 3 I_2 + 4 K_2SO_4 + Cr_2(SO_4)_3 + 7 H_2O$. And, $3 I_2 + 6 Na_2S_2O_3 = 6 NaI + 3 Na_2S_4O_6$ (sodium tetrathionate).

For Testing Iodine Absorption of Oils by Hübl Method: — Use thin glass-stoppered Erlenmeyer flasks (light weight) with cup-shaped or lipped necks to form a gutter around stoppers, which should be ground to fit.

Weigh out about 0.25 gram of the oil to be tested into each flask (one being a control), and add 10 c.c. chloroform to each. Introduce 25 c.c. No. 1. iodo-mercuric solution, consisting of equal volumes of (a) and (b), mixed 24 hours previously, into each flask. Insert stoppers and fill surrounding gutters with KI solution to absorb any iodine which might escape. Set aside in a dark closet for 24 hours. If necessary, add more of the iodo-mercuric mixture.

Two separate blank tests should be made at the same time on the iodo-mercuric solution, without any oil.

After 24 hours, remove stoppers, wash KI solution from necks into flasks, add sufficient distilled water, and more KI solution to prevent formation of HgI_2 .

The two oil mixtures and the two blanks are then each titrated cold with the standard $\text{N}/10$ "hypo" solution until nearly colorless, when a few drops of starch indicator are added, and the titration completed by discharging the bluish color.

WIJS SOLUTION FOR IODINE ABSORPTION

A solution of iodine monochloride in glacial acetic acid. Keeps better and acts quicker than the Hübl reagent, although the results are slightly higher.*

The iodine monochloride solution (viscous) is prepared by dissolving 13 grams iodine in one litre of strictly C. P. glacial acetic acid (99.5 per cent), with the aid of gentle heat.

Cool and test 25 c.c. for iodine content by titration with thiosulphate and starch indicator.

Pass pure chlorine gas through the rest of the solution until the dark red iodine color changes to orange yellow, indicating transformation of I to ICl . A portion of this, titrated with thiosulphate, should show "double" the halogen content originally found.

For any excess chlorine present an equivalent weighed amount of iodine is dissolved in the solution.

With Oils: — The method is conducted like the Hübl, using chloroform, potassium iodide, standard sodium thiosulphate and starch indicator. On account of viscosity it is necessary to measure or drain the solution carefully from the burette at constant temperature for comparative results. Time of absorption is 15 minutes for non-drying oils, and a less period for drying oils.

* Berichte, 1898, 31, 750-752; Analyst, 1898, p. 240; 1899, p. 257; Sherman's Organic Analysis.

APPROXIMATE FIGURES FOR OILS, FATS, AND WAXES

Oil.	Per cent KHO req.	Koettstor- fer figure.	Sapon. equivalent.	Iodine ab- sorption.
Almond oil (sweet).....	19.0	190	295	97
Bayberry wax (myrtle).....	21.0	210	267	10
Beeswax.....	9.5	95	591	9
Blown oils.....	21.0	210	267	63
Butter fat.....	22.8	228	246	32
Cacao butter.....	19.7	197	284	37
Carnauba wax.....	8.5	85	660	9
Castor oil.....	17.9	179	313	84
Cocoonut oil.....	25.9	259	216	9
Cod liver oil.....	18.2	182	308	140
Corn (maize) oil.....	19.1	191	294	118
Cottonseed oil.....	19.4	194	289	108
Cottonseed stearin.....	19.4	194	289	90
Croton oil.....	21.0	210	267	103
Horse fat.....	19.7	197	284	84
Japan wax.....	22.0	220	255	5
Lard (solid).....	19.2	192	292	60
Lard oil.....	19.5	195	287	70
Linseed oil.....	19.0	190	295	180
Menhaden oil.....	18.9	189	297	155
Mineral oil.....	Nil	Nil	Nil	10(?)
Neatsfoot oil.....	19.4	194	289	70
Olive oil.....	19.0	190	295	82
Palm oil.....	20.1	201	279	54
Paraffin.....	Nil	Nil	Nil	10(?)
Peanut (arachis) oil.....	19.1	191	294	95
Poppyseed oil.....	19.3	193	290	138
Rape (Colza) oil.....	17.5	175	320	100
Rosin oil.....	20(?)	20(?)	(?)	50
Sesamé oil.....	19.1	191	294	108
Sperm oil.....	13.5	135	415	84
Spermaceti.....	12.7	127	442	2.5
Stearic acid.....	19.7	197	284	Nil
Oleic acid.....	19.9	199	282	90
Palmitic acid.....	21.9	219	256	Nil
Sunflower oil.....	19.2	192	292	125
Tallow (solid).....	19.5	195	287	40
Tallow oil.....	19.7	197	284	70
Tung oil.....	19.4	194	289	100
Whale oil.....	19.0	190	295	120
Wool fat.....	9.0	90	623	36

For the analysis of shellac* Langmuir employs a Wijs solution of different strength, specifying "glacial acetic acid diluted with water to 99 per cent (melting-point 14.8° C.)."

HANUS SOLUTION FOR IODINE ABSORPTION

A modification of the Wijs solution, in which bromine is substituted for chlorine, forming iodine bromide.

13.2 grams iodine are dissolved in a portion (800 c.c.) of C. P. glacial acetic acid (99.5 per cent), using gentle heat. After cooling 3 c.c. bromine is added with sufficient glacial acetic acid to bring volume to one litre. An excess of iodine is permissible.

Not so rapid as the Wijs solution, requiring an hour for the absorption test. The results approach Hübl figures.

ADULTERATIONS IN BUTTER AND MILK

Before Testing, Prepare Clear Butter Fat, thus:—Melt a quantity of butter sample in a large test-tube by immersing in a water or steam bath. Add an equal bulk of hot water, cautiously shake or mix to avoid ejection of contents by any steam present, cork up, then invert the tube and chill in that position. When cold uncork and pour off water containing curd, coloring matter, or other substances. Repeat the operation, if necessary, to obtain as pure fat sample as possible, and thus remove the last portions of curd and salts. Reserve clear butter fat for special tests.

The milky or cloudy solution with the curd in suspension may be filtered and examined for salts.

Residue on Filter:—Curd, starch, mineral matter, chrome yellow, etc.

Filtrate (aqueous solution):—Examine for soluble salts, as borax, saltpeter, alum, etc.

* J.S.C.I., 1911, No. 13, p. 786.

TESTS ON CLEAR FAT SAMPLE

Oleomargarine. The sample, heated in a platinum or porcelain dish, sputters with an odor of frying beef suet, while clear butter fat froths quietly and may rise over dish.

Butter Fat, heated or saponified with alcoholic potash, then a little extra alcohol and a few drops of concentrated H_2SO_4 added, develops a pineapple or fruity odor known as ethyl butyrate. (Distinction from oleomargarine as such.)

Solubility of Butter Fat in Amyl Alcohol and Ether Mixture (containing 40 volumes of the former to 60 of the latter).

1 gram butter fat dissolves in 3 c.c. at 28°C .

1 gram lard requires 16 c.c. at 28°C .

1 gram tallow requires 50 c.c. at 28°C .

1 gram stearin requires 350 c.c. at 28°C .*

For Coloring Matters in Butter Fat. Such as annatto, turmeric, or saffron. Dissolve 5 grams of the filtered fat in 25 c.c. carbon bi-sulphide or 50 c.c. ether, and shake with a little water made faintly alkaline with caustic potash or soda. The alkaline water takes up the coloring matter. Evaporate a portion of the solution and test with H_2SO_4 .

Annatto. A blue or violet color should result, changing to green, and finally brown.

Saffron. No green coloration.

Genuine butter may give a dirty green, but without any bluish color.

Turmeric. Test a portion of the alkaline water with alcohol made faintly alkaline with ammonia. The presence of turmeric would be indicated by a brownish coloration.†

* See U. S. Dep't Agric., Bulletin No. 13, p. 75.

† Ibid., pp. 27-28.

Boric Acid in Milk. Take 50 or 100 c.c. sample and make quite strongly alkaline with lime water (calcium hydroxide). Evaporate and incinerate. All boric acid remains in the ash. Dissolve ash in minimum quantity of concentrated hydrochloric acid. Dilute with a little water and test with a strip of turmeric paper, allowing same to soak a few minutes. Remove and dry in air. Boric acid would be indicated by the cherry-red color imparted to the paper, and which with dilute alkalis would be altered to green or blue.*

Rapid Test:—One drop of milk sample in a porcelain dish, two drops concentrated HCl, and two drops saturated turmeric solution. Dry on water-bath. Cool and add a drop of ammonia on glass rod.

Slaty-blue to green color indicates borax or boric acid. Sensitive to $\frac{1}{1000}$ grain of borax.†

Salicylic Acid in Milk. Coagulate milk sample with HCl, filter off curd, and shake whey with ether. Separate ether solution. Evaporate the ether and the salicylic acid will be sufficiently pure for testing.

Best Test:—Violet color produced by a solution of ferric chloride (as neutral as possible).

LIST OF COMMERCIAL TESTS ON OILS AND FATS

The tests applied are physical and chemical

Viscosity. The most important physical test for oils, especially petroleum oils used for lubrication, is that obtained with a viscosimeter, of which there are standard or specified forms in the market. The oil is allowed to flow from a reservoir at a specified temperature, through a

* Consult Sherman's Notes on Organic Analysis, and Leffman and Beam's Milk and Milk Products.

† Annual Report, Chemist, Philadelphia Board of Health, 1896.

standard orifice, and the rate of flow compared with that of a standard sample under the same conditions, or with any other liquid standard. This test is not, however, adapted for certain "high temperature" greases.

Specific Gravity. It is customary to make the determination at 15.5°C. and also at 99°C. , water being used as a standard. For small samples, use the Sprengel tube at 99°C. With larger samples, the Westphal balance is very convenient and accurate, especially if the sample is very viscous or even solid at ordinary temperatures, when a special plummet is employed at 99°C.

Melting-point. (For solid fats and waxes.) Ordinarily the substance is first melted and allowed to congeal on the bulb of a thermometer, which is then immersed in water and the temperature gradually raised until the substance melts from the bulb. Preferably, it may be determined by introducing a small amount of the melted substance into a capillary tube, which is cooled and attached to the stem of a thermometer; then the same is immersed in water and the temperature gradually raised, stirring carefully, until the substance begins to melt as described under Fatty Acids and Waxes.

Solidification-point. (For liquid fats and oils.) In this test a freezing-mixture is necessary, such as ice and salt, or niter and water, or solid carbonic anhydride in ether, the latter for very low temperatures. The freezing mixture is placed in a suitable bottle resting on paper or other non-conducting material. A test-tube containing the oil, in which a delicate thermometer is suspended, is then inserted in the freezing-mixture. The temperature at which the oil just begins to flow is known as the "cold test." Should flocs or crystals form touching the thermometer, the "chilling" or "solidifying-point" has been reached. Stir and note any rise of temperature due to crystallization.

Flash-point Test. Generally used on illuminating oils and oils intended for hot machinery. A simple method consists in heating the sample in a porcelain dish or capsule with a thermometer suspended in the oil, and noting the temperature at which the vapors begin to flash when brought into contact with a lighted jet or taper. The heating should be gradual over a low Bunsen flame. Specifications may require the use of special apparatus, as the New York State Tester or other form with covered top. Results are expressed in degrees Fahrenheit (commercially).

	Approx. flash-point.	Fire point.
Illuminating oils.....	100° to 120° F.	110° to 150° F.
Lubricating oils.....	400° to 500° F.	475° to 575° F.
Fatty oil.....	350° to 525° F.	460° to 645° F.

Moisture or Water Content. Dilute a known quantity of sample with excess of gasoline in a tall narrow cylinder. Shake, cover, and let stand over night. Water, if present, collects in a globule on bottom. Remove same, and measure or weigh. With semi-solid substances apply gentle heat and add enough petrolic ether to prevent mass from solidifying on cooling, so that water globules may collect.*

Free Acid Test. Litmus is unreliable for this test. Acidity may be due to acid used in refining or to rancidity from fatty substances, and may be determined in terms of sulphuric or oleic acid, by extracting a known weight of sample with warm alcohol, neutral to phenol-phthalein, and titrating with N/10 alkali. For a simple test an alcoholic phenol-phthalein solution, made pink with a few drops of caustic alkali, is shaken with little oil. Acidity discharges color. Also, heat strips of copper in oil for a given time and note action.

* Consult Wright, Oils, Fats, Waxes, etc., 1894, p. 122.

Maumené Test. Rise of temperature, when an oil is mixed with strong sulphuric acid, is greater with drying than with non-drying oils. The acid should be of known strength, preferably 89–90 per cent as determined by titration, so that 50 c.c. water mixed with 10 c.c. acid will give a rise of about $35^{\circ}\text{C}.$ * All apparatus, water, acid, and samples should be of same room temperature. Place 50 c.c. oil in small (150 c.c.) dry deep beaker packed in larger beaker or cup with cotton waste to prevent radiation. With fine pipette add slowly 10 c.c. acid, stirring with thermometer until maximum temperature is reached.

On account of "frothing," produced by linseed and other drying oils, dilute 25 c.c. sample with 25 c.c. mineral oil, and stir in slowly 10 c.c. acid, having previously ascertained temperature rise of 25 c.c. mineral oil. From the temperature rise of mixture, subtract the temperature rise of 25 c.c. mineral oil, and multiply the difference by two for the temperature rise of 50 c.c. sample.† For "specific temperature reaction," multiply oil rise by 100 and divide by rise obtained with water (50 c.c.) under the same conditions.

Solubility Tests. Behavior with solvents as chloroform, ether, petrolic ether, gasoline, absolute alcohol, acetone, glacial acetic acid, acetic anhydride, benzol, carbon tetrachloride, amyl acetate, etc., should be noted.

As a rule, ordinary soaps or oils saponified with caustic alkali are insoluble in gasoline or ether, but quite soluble in alcohol or water.

Free or unsaponified oils, on the other hand, are quite soluble in gasoline or ether, imperfectly soluble in alcohol and immiscible with water.

Cholesterol and allied unsaponifiable matter, occurring in animal fats and oils, is soluble in ether and petrolic ether

* Sherman, Jour. Am. Chem. Soc., 1902, p. 271.

† Gill, Oil Analysis, 1898, p. 47.

as well as absolute alcohol, and, therefore, it is not unusual to find it in small amounts in the free oil extract.

As an exception and in sharp distinction from other oils, the true castor oil is very soluble in absolute alcohol and quite insoluble in petrolic ether. Sperm oil, being a liquid wax, is soluble to a clear solution in boiling absolute alcohol, while linseed oil under similar conditions gives a cloudy solution. Chloroform and carbon tetrachloride are excellent solvents for halogen absorption tests, but sink with immiscible solutions. Acetic anhydride takes up rosin oil, but is generally immiscible with others.

In glacial acetic acid, mineral and rape oils are insoluble, while castor and rosin oils are completely soluble at ordinary temperatures. Other oils, soluble in the hot, give turbid solutions on cooling. While hot the difference in solubility serves to detect rape in linseed, and affords a separation of mineral from both linseed and rosin oils.

Valenta Turbidity Test. Interesting, also important. Equal volumes of the oil and glacial acetic acid are heated in a test-tube with frequent shaking till dissolved. A thermometer is then immersed in the liquid, which is allowed to cool slowly. The temperature at which the first sign of cloudiness is noticed is the "turbidity temperature," which varies considerably according to conditions, strength of acid, etc.

High turbidity, 85°-100° C.	Low turbidity, 25°-64° C.
Cottonseed oil Neatsfoot oil Almond oil Sperm oil Lard and tallow Olive oil	Linseed oil Menhaden oil Cocoanut oil Palm oil Butter fat Commercial oleic acid

Insoluble — Mineral and Rape Oils.

Completely Soluble — True Castor and Rosin Oils on cooling.

Gumming Test. Adapted mostly for lubricating oils and greases. Mineral, lard, and sperm oils, tallow, horse, and bone fat are non-drying, while linseed, tung, rosin, cottonseed, rape, and menhaden oils tend to thicken and "gum" on heating. Spread sample on watch-glass or glass plate and expose to a temperature of 100°C. , for three or four hours.

Drying Test. Applicable to paint and varnish oils. Raw linseed, applied with brush to ground glass plate, usually requires three or four days to become "tacky" dry by itself. With driers the same oil may dry in from three to twelve hours under similar conditions.

Livache Drying Test. Principally for linseed oil. Depends on the use of finely divided precipitated lead, prepared by suspending a strip of zinc in lead acetate solution, then washing successively with water, alcohol, and ether, and drying in a dessicator. Carefully spread out one gram of precipitated lead in a 3-inch watch glass and weigh whole. With a fine pipette distribute 0.5 gram (20 drops or more) in separate drops over surface of the lead and again weigh. On exposure the lead accelerates the absorption of oxygen by the oil. Make weighings every 18 or 24 hours for three or four days until maximum is reached. The greatest increase in a given time indicates the drying quality. The absorption is much less with corn and cottonseed oils.

Saponification Test. As described under Koettstorfer's Process. See methods given for "fatty acids" and "waxes." Mineral oil, rosin oil, and other hydrocarbons (being non-saponifiable) are separated from saponified matter or aqueous soapy solutions by extraction with ether, gasoline, or other immiscible solvent.

Iodine Absorption Test. As described under Hübl Method.

Bromine Absorption Test. As described under Linseed Oil.

Action of Nitric Acid on Different Oils. Use concentrated acid having a specific gravity of 1.42. Shake equal parts of oil and acid in large test-tube, and note change of color.

Oil.	First action.	After 5 minutes.
Sweet almonds.....	Flesh tint.....	Cherry red.
Lard oil.....	Lemon or yellow to brown.	Chocolatered to brownish red.
Sperm oil.....	Orange yellow.....	Coffee brown.
Raw linseed.....	Olive green, immediately. Then dark brown to lighter shade.	Brown to reddish brown.
Olive oil.....	Greenish.....	Dirty brown.
Cottonseed (prime) ..	Brown.....	Chocolate brown; finally deep blood red.
Turpentine.....	Reaction violent or dangerous.	

Halphen's Reaction for Cottonseed Oil

Use a One Per Cent Solution of Sulphur in Bi-sulphide of Carbon.

Mix equal proportions each of the reagent, the oil to be tested, and amyl alcohol in a large test-tube, and heat cautiously till boiling subsides.

Then place tube and contents in a boiling, saturated solution of common salt and heat for an hour or more until an orange or red color develops, indicating presence of cottonseed oil.

This test is considered one of the most reliable for detecting adulteration with cottonseed oil.

Hexabromide Test for Linseed and Fish Oils

Mix 2 c.c. oil sample with 40 c.c. ether, acidified with glacial acetic acid. Cool to 5° C. Add bromine drop by drop till a permanent brown solution forms. Let stand

2 or 3 hours. Filter through asbestos, and wash precipitate successively with little acetic acid, alcohol, and ether; then dry and weigh precipitate.

Linseed oil	yields 23.0 to 25.0%	hexabromide.
Shark oil	yields 22.0%	hexabromide.
Whale oil	yields 25.0%	hexabromide.
Cod oil	yields 35.5%	hexabromide.
Cod-liver oil	yields 42.9%	hexabromide.

China-wood oil, corn, and cottonseed oils practically none.*

Liebermann-Storch Reaction for Rosin Oil

Shake equal volumes of the oil sample and acetic anhydride in a test-tube. Warm gently, then cool, and pipette off the anhydride which is tested with a drop of concentrated sulphuric acid. A fine violet coloration indicates the presence of rosin oil or resinous matter. Cholesterol is stated to give a similar result.†

Baudoin's Test for Sesamé Oil

In a large test-tube, dissolve 0.1 gram cane sugar in 10 c.c. hydrochloric acid of 1.2 sp. gr., then add 20 c.c. oil and shake thoroughly for one minute.

Gradually, a pinkish tint develops, and the aqueous portion, as it separates, assumes a crimson or raspberry-red color which deepens on standing.

The color is probably due to the action of furfural produced by acid and sugar. The test is sensitive to 1 per cent sesamé oil in admixture.

Olive oil may show a slight reddening in the aqueous portion, but, as a rule, exhibits only a greenish tint in the oily layer; while, if much sesamé oil be present, the reddish

* Hehner and Mitchell, *The Analyst*, 1898, p. 310.

† Gill, *Oil Analysis*, 1898, p. 99.

coloration will be observed in both oily and aqueous layers after standing some time.

Villivechia modified the test by employing a 2 per cent solution of furfural in 95 per cent alcohol. Of this 0.1 c.c. is added to 10 c.c. hydrochloric acid (sp. gr. 1.2), which is then shaken with 10 c.c. of the oil.

Tocher's Test for Sesamé Oil

Depends on the use of pyrogallol, 1 gram of which is dissolved in 15 c.c. hydrochloric acid (sp. gr. 1.2) and shaken in a separatory funnel with 15 c.c. oil sample. The aqueous portion is then drawn off and boiled 5 minutes, when, if sesamé oil be present, it should appear red by transmitted light and blue by reflected light.

Renard's Test for Peanut Oil *

Depends on the separation of arachidic acid, the test having been modified by various investigators.

Twenty grams of the sample are saponified with alcoholic potash, then phenolphthalein is added, and the solution neutralized exactly with acetic acid. The whole is then washed into 200 c.c. of a boiling 10 per cent lead acetate solution, contained in a 500-c.c. flask.

Continue boiling one minute. Cool by whirling flask in cold water, causing lead soaps to adhere to sides of flask.† Pour off water and excess of lead acetate, wash soaps with cold water, followed by 90 per cent alcohol. After draining off alcohol, as much as possible, add 200 c.c. ether (or petrolic ether), cork, and let stand until disintegrated; then connect with reflux condenser and digest over water-bath for five minutes.

* *Compt. rend.*, 1871, lxxiii, 1330; *Comm. Org. Anal.*, 1899, Vol. II, pt. 2, p. 134; *Analyst*, 1898, p. 273.

† *Sherman's Organic Analysis*.

Cool to 15° C. and allow to settle. Filter, wash with ether, and transfer to beaker with boiling water acidified with hydrochloric acid. Then, add excess of dilute hydrochloric acid and 200 c.c. water, and boil to liberate fatty acids as an oily layer.

Allow to cool until layer has solidified, and crystals of lead chloride have formed on bottom of beaker. Remove cake of fatty acids, treat again with boiling water, cool, collect, and dissolve in 100 c.c. boiling 90 per cent alcohol. Cool to 15° C. over night to permit fatty acid to crystallize; then filter and wash crystals with 20 c.c. 90 per cent alcohol (note volume of filtrate).

Dissolve crystals with hot alcohol (50 c.c.) into weighed dish, evaporate dry on water-bath, and weigh. Add correction of 0.0025 gram for each 10 c.c. filtrate and washings at 15° C.; or, 0.0045 gram, if temperature is 20° C.

Remarks: — Using the above method, the writer obtained from 30 grams peanut oil, 1.58 grams pearly spangles arachidic acid (= 5.26 per cent), having a melting-point of 73° C. The test is somewhat tedious. The arachidic acid is equivalent to about 5 per cent of the peanut oil, and therefore becomes a measure of the amount of such oil present in the sample.

Elaidin Test for Oils

Oils containing much olein, as tri-olein, $C_3H_5(C_{18}H_{33}O_2)_3$, give on treatment with nitrous acid, a cake of solid white or yellowish-white elaidin, having a melting-point of 32° to 38° C.

Similarly, oleic acid is converted into isomeric crystalline elaidic acid, $H.C_{18}H_{33}O_2$, with a melting-point of 45° C.

Olive, peanut, almond, and lard oils give a hard elaidin, while corn, cottonseed, sesamé and rape oils become pasty

and the drying oils, as linseed, poppyseed, menhaden, etc., remain unaltered or liquid.

Temperature is an important factor in the test, 15°C . being recommended for the best results; certainly, not over 25°C .

Copper Method:—About 5 c.c. nitric acid, sp. gr. 1.34 (strength about 2 : 1), is placed in a small wide-mouthed bottle or large test-tube with 10 c.c. oil to be tested; then 0.5–1.0 gram copperfoil or wire, thoroughly moistened with dilute acid to “shed” the oil, is added and the whole immersed in water at 15°C . The action is allowed to proceed slowly with occasional shaking until the copper is dissolved, the contents being kept as cool as possible. Let stand cold one to three hours. Olive and peanut oils give a hard elaidin in about two hours.

Should the evolution of gas become too rapid and the solution greatly overheated, the formation of elaidin will be retarded or possibly prevented.

Should the copper become coated with oil first, it will “shed” the acid, and the action will be incomplete.

To avoid these conditions, keep the contents cooled to 15°C ., and cleanse the copper pieces thoroughly in very dilute HNO_3 before dropping into oily layer, through which they sink with moistened surfaces into the acid underneath.

Mercury Method:—Mercury may be substituted for copper, thus: In a test-tube, place 1 gram mercury (globule, size $\frac{1}{2}$ pea) and 5 c.c. cold nitric acid, sp. gr. 1.34 (about 2 : 1), which is covered with 10 c.c. oil. When action commences, cool slightly and shake occasionally as gas rises into oil (which, in the case of olive oil, assumes a greenish tint). Finally, when mercury is dissolved, mix well and set aside in cold water.

This test may be modified by dissolving, in the cold, 1 gram mercury in 7 or 8 c.c. cold nitric acid (sp. gr. 1.43),

so as to produce an emerald-green solution. 2 or 3 c.c. of this cold, freshly prepared, green solution is placed in a test-tube, then 10 c.c. of oil added, thoroughly shaken for a minute, and the tube allowed to stand in cold water. If too much acid and mercury are used in proportion to the oil, the mixture is liable to become hot and froth over suddenly.

Potassium Nitrite Method :— A different, but very neat, method depends on the use of potassium nitrite instead of metals.* For this purpose a large test-tube is used and 1 volume water, 2 volumes nitric acid (sp. gr. 1.45), and 10 volumes oil are mixed by vigorous shaking. (At this point, certain color reactions may be observed.) Then, after a short time, a saturated solution of potassium nitrite (4 or 5 c.c.) is allowed to run down inside the tube, which is immersed in cold water, and the rate and kind of solidification noted. The evolution of gas takes place readily and some frothing occurs which may be easily controlled. With olive and peanut oils practically the entire mass solidifies, excepting a little aqueous liquid underneath; while corn oil assumes a peach-blow tint and finally gives considerable froth and a liquid orange-red layer.

Cottonseed and rape oils behave somewhat like corn oil, but give a frothy, orange-colored, semi-solid after 3 hours in the cold, according to the writer's observations.

With drying oils the evolution of gas and action is slower.

Tung, or China-wood, oil gives a coffee-colored pasty liquid; and linseed a creamy liquid after 3 hours in the cold.

Undoubtedly, the potassium nitrite method for elaidin merits preference as a simple and convenient test for distinguishing the drying and non-drying oils, surpassing in efficiency the more economical copper method.

* Andés, *Drying Oils*, etc., 1901, pp. 3 and 4.

COMPARISONS OF VEGETABLE OILS

Oil.	Constants.	Solubility.	Remarks.
True castor from castor bean (<i>Ricinus communis</i>). Contains ricinolin and hydroxystearin as well as active cathartic principle.	Sp. gr. (high) 0.960 at 15.5° C., — suspicious, under 0.958. Sapon. number, 173-186. Iodine figure, 82-90. Sp. temp. react., 84-94. Soft elaidin.	Soluble in absolute alcohol (important), and in glacial acetic acid at ord. temp. (distinction from rape and mineral oils.) Insoluble in petroleic ether (distinction from other oils). — miscible with mineral oils — req. adding lard oil or other fatty oil.	<i>Uses:</i> Employed in medicine and soap-making. For "turkey red oil," (ammonium ricinol sulphate), by action of sulphuric acid and neutralizing with ammonia. <i>Adulterants or substitutes:</i> Blown oils made from rape or cottonseed, and differing in solubilities and constants from true castor oil.
Blown oils, from rape, cottonseed, linseed, etc.; by passing air through oil, heated 70-85° C.	Sp. gr. 0.967, or over, at 15° C. Often denser than castor. Sapon. number, 197-213. Iodine figure, 56-63.	Quite soluble in petroleic ether (distinction from castor). Almost insol. in alcohol (unlike castor). Perfectly miscible with mineral oils (unlike castor).	<i>Uses:</i> For lubrication and, in case of linseed, for rapid drying and varnish coatings. <i>N. B.</i> — Castor oil, similarly blown, becomes more viscous and miscible with mineral oil and petroleum hydrocarbons (not so, ordinary castor oil). <i>See</i> Oils, Fats, Waxes, etc., Wright, 1894, pp. 320-321.
Almond oil, — the fixed expressed oil in both sweet and bitter almonds. Not to be confounded with the essential bitter oil, as benzaldehyde, from amygdalin. Mainly olein.	Sp. gr. 0.915 to 0.920 at 15° C. Sapon. number, 190. Iodine figure, 93-102. Sp. temp. react., 95-120. Solid elaidin.	Soluble in 24 parts cold abs. alcohol. Soluble in ether, chloroform etc.	<i>Uses:</i> Principally, cosmetics, emulsions, and ointments. <i>Adulterants:</i> Cottonseed, detected by Halphen reaction, high Mäuméné figure, and HNO ₃ test. Peanut, by Renard's test (arachidic acid). Lard, by odor on heating, M. P. of fatty acids, and chilling to -10° C. (white, solid). Sesamé, by Baudoin test.
Peanut or arachis oil from common peanut, by cold pressing. Pale yellow to colorless. Nutty odor and flavor. Contains palmitine, olein, linolin, and arachidin.	Sp. gr. 0.915 to 0.922 at 15° C. Sapon. number, 186-197. Iodine figure, 88-108. Sp. temp. react., 105-140. Solid elaidin.	Soluble in ether, chloroform, etc. With glacial acetic acid, high turbidity test, 87°-112° C.	<i>Uses:</i> Salad oil, burning oil and soap-stock. Characteristic test — arachidic acid by Renard's method. <i>Adulterants:</i> Cottonseed detected by Halphen's reaction and M. P. fatty acids (peanut, 28° C.). Rape lowers sapon. number. Poppy has high iodine figure, 138. Sesamé, by Baudoin test.

COMPARISONS OF VEGETABLE OILS — Continued

Oil.	Constants.	Solubility.	Remarks.
Poppy-seed oil from common poppy. Colorless to yellowish. Little odor and pleasant taste. Mainly linolin and olein.	Sp. gr. 0.924 to 0.927 at 15° C. Sapon. number, 189-197. Iodine figure, 133-143. Sp. temp. react., 200-240. Liquid elaidin.	Soluble in 25 parts cold abs. alcohol; and in 6 parts boiling. Soluble in ether, chloroform, etc.	<i>Uses:</i> Rapid drying oil for artists' colors. Also, as an edible oil (no narcotic effect). Constants higher than those for olive and sesamé oils.
Rape or colza oil from seeds of <i>Brassica campestris</i> . Crude, brown, with peculiar odor and harsh taste. Refined, light yellow and almost odorless. Contains olein, stearin, and erucin.	Sp. gr. 0.915 at 15.5° C. Sapon. number, 178-185. Iodine figure, 96-105. Sp. temp. react., 125-155. Pasty elaidin.	Almost insoluble in eq. vols. glaci. acetic acid (distinction from other oils except mineral).	<i>Uses:</i> Burning oil and adulterating olive. Viscosity greater; sp. gr., sapon. number, and sp. temp. reaction lower than other seed oils. <i>Usual adulterants:</i> Cottonseed, linseed, menhaden, and possibly oleic acid.
Olive oil from fruit of the olive tree by pressure or by extraction. Color, yellow to greenish. Mainly olein, with 25% palmitin, stearin, etc. Free fatty acid may vary from 1% to 24%.	Sp. gr. 0.914 to 0.918 at 15° C. Sapon. number, 186-196. Iodine figure, 77-90. Sp. temp. react., 90-110. Solid white elaidin in few hours.	Slightly soluble in alcohol. Soluble in ether, chloroform, etc. With glaci. acetic acid it gives high turbidity test, 85°-110° C.	<i>Uses:</i> Salad oil. <i>Adulterants:</i> The iodine and Maumené figures are increased by corn, cottonseed, peanut, rape, and sesamé oils. Rape lowers saponification number. Cottonseed detected by Halphen reaction. A pasty yellow elaidin would indicate adulteration. Olive, on chilling to -10° C., thickens and becomes turbid.
Corn or maize oil, from germ of Indian corn. A by-product from starch-works and distilleries. Color, golden brown to straw yellow. Nearly odor, unless deodorized. Contains olein stearin, palmitin, linolein, ricinolin, etc.	Sp. gr. 0.921 to 0.923 at 15° C. Sapon. number, 185-192. Iodine figure, 110-120. Sp. temp. react., 160-200. Pasty elaidin.	Soluble in ether, acetone, chloroform, etc. With glaci. acetic acid, turbidity temp. varies from 44° to 80° C.	<i>Uses:</i> Soap-making (easy saponification), salad oil, rubber substitutes, paint, and mixed lubricants. Also, for adulterating other oils. Constants lowered by mineral and rosin oils, latter detected by Liebermann-Storch reaction. <i>N. B.</i> — Phytosterol (unsaponifiable) occurs in notable amount, 1.4%.
Cottonseed oil from seeds of cotton plant by pressure. Crude, red or black color. Refined, pale yellow with a pleasant taste. Contains olein, linolin, stearin, etc.	Sp. gr. 0.922 to 0.925 at 15° C. Sapon. number, 192-196. Iodine figure, 102-115. Sp. temp. react., 146-175. Pasty elaidin (brownish).	Soluble in ether, chloroform, etc. With glaci. acetic acid, high turbidity test, 90°-110° C.	<i>Uses:</i> "Cottolene" for cooking; also, soap and adulterating other oils. Rarely adulterated itself. Confirm with HNO ₃ color test and Halphen's reaction. Crude cottonseed on saponification gives reddish soap. Fatty acids, M. P., 38° C.

COMPARISONS OF VEGETABLE OILS—Continued

Oils.	Constants.	Solubility.	Remarks.
Sesamé oil from seeds of <i>Sesamum indicum</i> . Yellow, with bland taste and no odor. Contains olein, stearin, palmitin, and gummy matter.	Sp. gr. 0.920 to 0.925 at 15° C. Sapon. number, 187-195. Iodine figure, 102-112. Sp. temp. react., 140-175. Pasty elaidin.	Soluble in ether, chloroform, etc. With glac. acct. acid—(some color from gummy matter)—turbidity test, 87° C. Acetic solution treated cold with eq. parts mixture of conc. H ₂ SO ₄ and HNO ₃ , green to yellow.	<i>Uses</i> : Edible oil, soap-making, etc. <i>Adulterants</i> : Peanut and rape lower constants. Poppy raises constants. Cottonseed detected by Halphen's Reaction. <i>Test for sesamé</i> : Baudouin's reaction with furfural, red or crimson color.
Croton oil from seeds of <i>Croton tiglium</i> . Pale yellow to brown. Taste mild to burning. Contains tigliin, crotonin, stearin, palmitin, laurin.	Sp. gr. 0.940 to 0.960 at 15° C. Sapon. number, 207-214. Iodine figure, 101-105. Sp. temp. react., 103 (Hyde). No elaidin (thick liquid).	Soluble in abs. alcohol (like castor). Soluble in petroleic ether (unlike castor). Soluble in glacial acetic acid, turbidity, 58° C.	<i>Uses</i> : Strong purgative. Poisonous to skin (pustules). Vesicatory agent crotonol. Purgative principle unknown.
Tung, or China-wood, oil from seeds of <i>Aleurites cordata</i> and <i>Elaeococca vernicia</i> of China and Japan. Reddish-brown, viscous, thick, with sour, smoky odor. Mainly olein and elaeomargarin.	Sp. gr. 0.934 to 0.960 at 15° C. Sapon. number, 190-197. Iodine figure, 150-170. Sp. temp. react., 200-370. Pasty elaidin (solid cake with cold HNO ₃ only).	Soluble in ether, chloroform, etc. Insol. in cold abs. alcohol. With glacial acetic acid, turbidity temp. 55° C. to 60° C. Shaken with warm satur'd solution iodine in carbon tetrachloride, suddenly jellies.	<i>Uses</i> : Rapid drying oil. Natural varnish for Chinese junks, and preserving wood. Gelatinizes on boiling or heating above 250° C., especially with driers. Mixed with other oils for paints, varnishes, etc. (See Andes, Drying Oils, Boiled Oils, etc., 1901.)
Linseed oil from flaxseed <i>Linum usitatissimum</i> . Amber color and sweet odor. Chiefly linolenin, with iso-linolenin, olein, and linolin.	Sp. gr. 0.931 to 0.937 at 15° C. Sapon. number, 186-196. Iodine figure, 170-190. Sp. temp. react., 270-330. Pasty or liquid elaidin.	When raw, soluble in ether, petroleic ether, carbon tetrachloride, turpentine, benzol, acetone, etc. Soluble in 10 parts of boiling absolute alcohol. With glacial acetic acid, turbidity, 61° C.	<i>Uses</i> : Drying oil for paints, varnishes, etc. With lime water forms emulsion (Carrou oil) for burns. <i>Adulterants</i> : Corn, cottonseed, menhaden, mineral, and resin oils. Forms addition products with bromine. The "Br. addition fig." and sp. temp. reaction is lowered by resin, rosin oil, and mineral oil, and also by corn and cottonseed oils.

COMPARISONS OF VEGETABLE OILS — *Concluded*

Oil.	Constants.	Solubility.	Remarks.
Sunflower oil from seeds of Helianthus annuus. Pale yellow with pleasant odor and mild taste. Chiefly linolin and olein.	Sp. gr. 0.920 to 0.927 at 15° C. Sapon. number, 188-196. Iodine figure, 118-135. Sp. temp. react., 107. Pasty elaidin.	Behavior with solvents similar to that of linseed oil.	<i>Uses:</i> In Russia as an edible oil. Also, for soap and paint manufacture.
Soya bean oil from seeds of self-nitrifying plant, grown in China, Japan, Manchuria, Minnesota, and Africa. Pale yellow color. Consists mostly of olein, linolin, and linolenin with a little palmitin.	Sp. gr. 0.922 to 0.933 at 15° C. Sapon. number, 191-194 (Hyde). Iodine figure, 127-186. Sp. temp. react., 273-282 (Hyde). Liquid or pasty elaidin.	Miscible with 3 parts hot abs. alcohol; cloudy in excess hot alcohol; almost insoluble cold. Easily soluble in cold ether, acetone, benzol, tetrachloride of carbon, etc. With glacial acetic acid, turbidity, 63° C. (Hyde).	<i>Uses:</i> Paint oil, substitute for linseed; also as an edible oil. Beans used as food and fertilizer. Heated to 500° F., the oil becomes bleached. By "blowing" at 500° F. can be thickened for linoleum industry and enamel paints, as well as printing inks and varnishes. (Article on Soya Bean Oil for Paint Purposes. — Toch, J. S. C.I., June, 1912.)
Cocoanut oil from nuts of palm Cocos nucifera. Usually semi-solid, white; M. P. 20° to 23° C. Liquid in summer. Mostly laurin; very little olein.	Sp. gr. 0.866 to 0.871 at temp. of 99° C. Sapon. number, 250-268 (high). Iodine figure, 8-10 (low).	Easily soluble in cold acetone and ether. Soluble in warm abs. alcohol, benzol, and carbon tetrachloride. With glacial acetic acid, turbidity, 40° C.	<i>Uses:</i> Medicine and ointments; night-lights, and "marine soaps." Saponifies slowly; requires conc. lye. Sodium laurate formed is more soluble in saline solutions than ordinary soaps, hence lathers with sea-water.
Palm nut oil from kernels of Elaeis guineensis. Semi-solid, white to pinkish; M. P. 20° to 32° C. Faint violet odor. Contains laurin, caprin, myristin, stearin, and olein.	Sp. gr. 0.866 to 0.873 at temp. of 99° C. Sapon. number, 246-250. Iodine figure, 10-13.	Similar to that of cocoanut oil. With glacial acetic acid, turbidity, 48° C.	<i>Uses:</i> Substitute for cocoanut oil, soap-making, etc. Resembles cocoanut oil, but contains a higher proportion of lower fatty-acid esters, and much more olein.
Palm oil from outer pulp of seed of Elaeis guineensis. Brownish to orange-red, buttery mass; often with tallow-like hardness, and peculiar odor. Contains palmitin, palmitic acid, olein, and water.	Sp. gr. 0.857 to 0.861 at temp. of 99° C. Sapon number, 196-206. Iodine figure, 50-57.	Soluble in petroleic ether, chloroform, etc. With glacial acetic acid, turbidity temp. varies with consistency.	<i>Uses:</i> Soap stock, candles, and greases. Rancidity increases with age, due to free fatty acids, which exert corrosive action on iron and steel. Consistency variable, and melting-point ranges from 27° to 43° C.

COMPARISONS OF ANIMAL OILS

Oil.	Constants.	Solubility.	Remarks.
Lard oil from lard by pressure. Mostly olein, with little palmitin and stearin. Odor of lard. Quite viscous. Light straw to brown color.	Sp. gr. 0.915 at 15° C. Sapon. number, 195. Iodine figure, 70. Sp. temp. react., 80-100. Solid elaidin.	Soluble in ether, chloroform, etc. With glacial acetic acid, turbidity, 100° C.	<i>Uses:</i> Burning oil for lighthouses, signal lamps, etc. Also used in pharmacy and for lubrication. <i>Adulterants:</i> Corn oil with high iodine figure (118), cottonseed oil by Halphen's reaction; and petroleum oils by flash-point and lower constants.
Tallow oil from tallow by melting, crystallizing stearin, and pressing same. Mostly olein, little stearin. Odor of tallow. Light yellow color. Quite viscous.	Sp. gr. 0.916 at 15° C. Sapon. number, 197. Iodine figure, 70. Sp. temp. react., 70. Solid elaidin.	Soluble in ether, chloroform, etc. With glacial acetic acid, turbidity, 100° C.	<i>Uses:</i> For mixing with other oils and for lubrication and soap-making. <i>Adulterants:</i> Cottonseed and mineral oils. Vegetable oils would raise constants, except sapon. number, and would give small amounts of phytosterol in distinction from cholesterol of animal oils.
Neatsfoot oil from shank bones and feet of neat cattle. Mostly olein, with some stearin, which deposits. Generally turbid, light yellow, little odor, bland taste.	Sp. gr. 0.915 at 15° C. Sapon. number, 195. Iodine figure, 70. Sp. temp. react., 70-100. Elaidin, sometimes solid.	Soluble in ether, chloroform, etc. With glacial acetic acid, turbidity, 102° C.	<i>Uses:</i> Lubricants and leather dressing. Mixed with mineral oil for loom and spindle machinery. <i>Adulterants:</i> Rape oil with low sapon. number, 175-178. Cottonseed and mineral oils.
Cod-liver oil from fresh livers of common cod. Pale yellow with fishy odor and taste. Mostly glycerides of unsaturated series, with stearin, palmitin, cholesterol, and traces of iodine.	Sp. gr. 0.920 to 0.930 at 15° C. Sapon. number, 180-190. Iodine figure, 130-180. Sp. temp. react., 240-280. Fatty elaidin.	Soluble in ether, chloroform, and slightly in alcohol. With glacial acetic acid, turbidity, 101° C.	<i>Uses:</i> Medicinal as an emulsion. <i>Adulterants:</i> Other fish oils and possibly seed oils. Has high iodine figure and sp. temp. reac. With bromine it gives precipitate of hexabromide. With H ₂ SO ₄ , fine violet or red spot test. Ordinary cod oil (dark brown) is used for leather dressing.

COMPARISONS OF ANIMAL OILS. — *Continued*

Oil.	Constants.	Solubility.	Remarks.
Menhaden oil from fish. Also menhaden. Color, yellow to brown. Contains olein, linolin, and glycerides of unsaturated series.	Sp. gr. 0.927 to 0.931 at 15° C. Sapon. number, 187-193. Iodine figure, 140-180. Sp. temp. react., 300-360. Pasty elaidin.	Soluble in ether, chloroform, etc. With glacial acetic acid, turbidity, 64° C.	<i>Uses:</i> Semi-drying oil for adulterating linseed oil, and mixing with various fish oils. Chief adulterant is mineral oil. Characterized by high iodine absorption and high sp. temp. reaction.
Whale oil from blubber of various whales, except sperm. Yellow brown, with disagreeable odor. Contains olein, palmitin, stearin, phytostein, valerin, free fatty acids, etc.	Sp. gr. 0.918 to 0.931 at 15° C. Sapon. number, 190-200. Iodine figure, 110-130. Sp. temp. react., 157. Pasty elaidin.	Soluble in ether, chloroform, etc. With glacial acetic acid, turbidity, 31°-83° C. (Allen.)	<i>Uses:</i> Whale oil soap, an insecticide. Also for burning, lubricating, and leather dressing. Boiled with caustic alkali it gives a reddish brown soap with offensive odor. Bromine gives insoluble hexabromide.
Sperm oil (liquid wax) from Physeter macrocephalus. Thin, light yellow, faint fishy odor. Mostly dodecatyl oleate. No glycerides.	Sp. gr. low, 0.878 to 0.884 at 15° C. Sapon. number, 125-145. Iodine figure, 80-85. Sp. temp. react., 100. Solid elaidin.	Soluble in ether, chloroform, benzol, etc. Insoluble in hot alcohol. Turbid with glacial acetic acid (boiling).	<i>Uses:</i> Most perfect lubricant for spindles and light machinery. Lower viscosity and gravity than any fixed oil at ordinary temperature. <i>Adulterants:</i> Chiefly mineral or hydrocarbon oils.

COMPARISONS OF ANIMAL FATS.

Fat.	Constants.	Solubility.	Remarks.
Tallow (beef or mutton) from fat of oxen and sheep. White or yellow. Mostly stearin and palmitin with one-third olein. (Thorpe's Industrial Chemistry; U. S. Dept. Agriculture, Bulletin No. 13, Part Fourth, 1889.)	Sp. gr. 0.860 at 99° C., or nearly so. Sapon. number, 192-198. Iodine figure, 32-45. M. P. 42-51° C.	Not very soluble in hot alcohol. Soluble in hot ether, petroleic ether, fusel oil, etc., with separation on cooling. With glacial acetic acid, high turbidity, above 95° C.	<i>Uses:</i> Soap, candles, and oleomargarine. <i>Possible adulterants:</i> Cottonseed stearin and coconut stearin (low melting-points). Tallow, after granulating in a vat, and pressing, gives oleo-oil (for butterine) and press-cake of oleo-stearin (for compound lards).
Lard from hog fat, leaf-lard from sheet fat covering intestines. White, when pure, and almost odorless. Consists of olein, stearin, and palmitin. (U. S. Dept. Agriculture, Bulletin No. 13, Part Fourth, 1889.)	Sp. gr. 0.860 at 99° C. or nearly so. Sapon. number, 195. Iodine figure, 50-70. M. P. 36-45° C.	More soluble than tallow. Partly soluble in alcohol. Soluble in warm ether and petroleic ether. In ether-alcohol, soluble hot; stearin separates on cooling. With glacial acetic acid, turbidity, 95° C.	<i>Uses:</i> Culinary purposes and as an emollient. <i>Adulterants:</i> Oleo-stearin, cottonseed-stearin and cottonseed oil. Microscopical test for beef-stearin: tuft-like needles from ether solution. Halphen's reaction might indicate cottonseed meal fed to hogs.
Bone fat from crushed bones by steam boiling or extraction with solvents. Yellow or brown, with offensive odor. Contains olein, stearin, palmitin, phosphate of lime, water, and impurities. Also cholesterol.	Sp. gr. about 0.855-0.860 at 99° C. Sapon. number, 170-195. Iodine figure, 45-60. M. P. 21-22° C.	Soluble in warm ether and petroleic ether. With glacial acetic acid, turbidity variable.	<i>Uses:</i> Candles, grease, and low-grade soaps. Usually contains calcium phosphate, removed by acid treatment. CaCO_3 in ash due to lime soaps present. Easily saponified. With the dried fat the lime soaps are soluble in petroleic ether, B. P. 85° C. (benzine). — Analysis of Oils, A. C. Wright, 1903, p. 205. Technical Analysis of Bone Fat, Analyst, 1898, p. 133.

SOME VEGETABLE FATS.

Substance.	Constants.	Solubility.	Remarks.
Cacao butter from beans of Theobroma cacao. A cream-white solid; softens in hand; melts in mouth. Chocolate odor. Mostly stearin and olein with some laurin, palmitin, and arachidin.	Sp. gr. 0.858 at temp. of 99° C. Sapon. number, 102-202. Iodine figure, 32-42. M. P. 24-34° C.	Soluble in ether, chloroform, benzol, etc. Soluble in 20 parts of hot absolute alcohol. With glacial acetic acid, turbidity temp. 105° C.	<i>Uses:</i> Pharmacy, ointments, facial massage, and manufacture of "chocolate creams." <i>Adulterants:</i> Tallow, coconut oil, paraffin, stearic acid, peanut, etc. <i>N. B.</i> — Husked cacao beans or "nibs," mixed with sugar, and ground to paste, constitute ordinary chocolate. Cacao powder is made from "nibs" partially deprived of cacao butter. (U. S. Dept. Agriculture, Bulletin No. 13, Part Seventh, 1892.)
Cottonseed stearin from cottonseed oil, after clarifying, by chilling, and cold pressing. Mostly stearin and palmitin.	Sp. gr. 0.864 to 0.869 at 99° C. Sapon. number, 103-190. Iodine figure, 88-104. M. P. 20-30° C.	Soluble in hot absolute alcohol and in ether; but deposits on cooling.	<i>Uses:</i> Manufacture of oleomargarine and butterine and for adulterating lard.
Japan wax, a vegetable tallow from berries of Rhus succedanea. Mostly palmitin and laurin, with some stearin and arachidin.	Sp. gr. 0.875 at 99° C. Sapon. number, 210-230. Iodine figure, 4-7. M. P. 45-56° C.	Soluble in boiling alcohol, ether, benzol, chloroform, acetone, carbon tetrachloride, turpentine, etc. (from which it congeals on cooling). Imperfectly soluble in petroleic ether.	<i>Uses:</i> Candles, grease mixtures, cosmetic ointments, furniture polishes, etc. Also, for adulterating beeswax.

GROUP TABLE OF PRINCIPAL OILS ARRANGED ACCORD-
ING TO SPECIFIC GRAVITY AND CONSTANTS.

Sp. gr. at 15° C.	Oils.	Sp. temp. reaction.	Iodine figure.	Elaidin.	Valenta.	Sapon. number
0.875-0.884	Sperm	100	80-90	Solid	98° C.	135
0.884-0.912	Oleic acid	.....	90	{ Elaidic Acid M. P. 45° C. }	27° C.	200
0.912-0.920	{ Almond Lard Neatsfoot Olive Peanut Tallow oil }	70-120	65-105	Solid	73-112° C.	195
	Rape					
0.920-0.937	{ Corn (maize) Cottonseed Sesamé Sunflower }	140-200	102-124	Pasty	85-110° C.	100
	{ Poppyseed Linseed Tung Menhuden }					
0.937-0.970	{ Castor Blown oils }	90 253	85 63	Soft ?	Soluble ?	178 200
0.966-0.990	Rosin oil	72	40-80	Oxidized	Soluble	2
0.780-0.920	Mineral oil	10-20	10-15	Nil	Insoluble	Nil
0.940-0.960	Croton oil	?	101-105	None	Soluble	210

LUBRICATING OILS

Sperm Oil. A liquid wax, described under "Waxes." One of the most perfect lubricants known, especially for light, high-speed machinery. It is pale yellow and limpid, with a slight fishy odor and low sp. gr., about 0.884 at 15.5° C. It does not "gum," or become rancid. Requires 12.5 per cent to 14.5 per cent KHO for saponification.

Lard Oil. Mostly olein, with some stearin and palmitine. Obtained by pressing lard and occurs in various grades from straw color to brown. Has been used in admixture with mineral oil for lubricating machinery, but is liable to become rancid, producing an acid reaction. Sp. gr. 0.915 at 15° C. Saponification, 19.5 per cent KHO.

Tallow Oil. Obtained by melting tallow, crystallizing the stearin to a granulated mass, and pressing to obtain the oil which consists mostly of olein. It has a light-yellow color and tallow-like odor. Sp. gr. 0.916 at 15° C. Saponification, 19.7 per cent KHO.

Neatsfoot Oil. From feet and shank bones of cattle. Light or turbid color, pleasant odor, and bland taste. Nearly pure olein; deposits stearin in cold weather. For lubrication it is generally mixed with mineral oil. Sp. gr. 0.915 at 15° C. Saponification, 19.4 per cent KHO.

Horse Oil, or Horse Fat. Obtained by rendering fat of dead horses. Quality variable, color dirty-white to brown, and consistency like lard or softer. Used in making soap, and, when refined, for adulterating neatsfoot and other oils. Sp. gr. 0.919 at 15° C. Saponification, 19.7 per cent KHO.

Bone Tallow or Marrow Fat. From shank bones of cattle — very little from horses' bones. Yellowish-brown grease with unpleasant odor. Generally contains phosphate of lime. Sp. gr. 0.915 at 15° C. Saponification, about 19.5 per cent KHO.

Rosin Oils. There are three or four grades of rosin oils, from water-white to dark brown, produced by distilling rosin in a retort with or without alkali, the distillates being:

(a) *Light distillate* (rosin spirit or pinoline), used as a solvent and turpentine substitute.

(b) *Heavy rosin oil distillate*, redistilled or rectified for various grades as: first run, pale; second run, brown; third run, dark. The purified, light-colored rosin oil has little odor or fluorescence, but a sharp taste, while the darker varieties possess more or less bluish or greenish reflex, strong taste, and "pitchy" odor.

Rosin oil has a high sp. gr. of from 0.980 to 1.100 at 15.5° C. — higher than usual for oils — and a high dextro-rotation in ether solution as observed in polarimeter. Its consistency is but little affected by cold weather.

Slightly soluble in cold absolute alcohol, and quite soluble in excess of hot absolute alcohol.

Soluble in ether, petroleic ether, chloroform, acetone, carbon tetrachloride, glacial acetic acid, and acetic anhydride.

It does not saponify, but tends to gelatinize with concentrated caustic soda at boiling temperature. So-called lime-rosin-oil soap* is apparently a combination in which freshly slaked lime, as "milk of lime," is slowly dissolved in the rosin oil, forming a dark-brown grease of buttery consistency.

Mineral and rosin oil in admixture may be separated by glacial acetic acid which dissolves rosin oil completely at ordinary temperatures, mineral oil being only sparingly soluble. The Liebermann-Storch reaction serves to detect rosin oils and resinous matter.

Rosin oil differs from linseed, corn, menhaden, and cottonseed oils in having a low "Koettstorfer figure" and low

* Schweizer's "Distillation of Resins," p. 71.

"Br. addition figure" (both under 20), but a high "Br. substitution figure" (40 to 100).

Uses: — Greases, printing-inks, boiled oil substitutes, etc.

Mineral Oil. Several grades of excellent lubricating quality, composed of hydrocarbons, are obtained by refining crude petroleum. Generally characterized by more or less "bloom" or greenish reflex noticeable in "engine oils," "cylinder oils," and the dark viscous grades for heavy bearings. Unsaponifiable, in distinction from fatty oils. Used as an adulterant and substitute for more expensive oils. Sp. gr. 0.800 to 0.950 at 15° C. Saponification, nil.

Presence of Soaps. Soda, potash, lime, and alumina soaps are occasionally employed as "thickening agents" for lubricating oils and greases. Excellent for heavy gearings or high temperature bearings — not for steam- or gas-engine cylinders, in which the soap might be decomposed.

Greases. Generally mixtures of mineral or rosin oils with animal oils or fats, lime or soda soaps, degreas, graphite, etc.

Cold "Set" or Axle Grease: — Stir rosin oil into fresh milk of lime paste, then, after standing 12 hours, incorporate mineral oil and allow to "set."

Boiled Grease: — The following three methods may be used. (1) Stir hot freshly prepared milk of lime (strained 40 mesh) into previously melted tallow, horse fat, or palm oil, and heat until soap is formed. Run off excess water if necessary, and spray in mineral oil at 190° F. (2) Prepare a hot soda soap "batch," run in cold mineral oil, agitate violently, and cool quickly. (3) Add soap shavings to hot mineral oil at 240° F., "fry out" moisture, and cool to stiff mass.*

* See Redwood's "Lubricants"; also, Hurst's "Lubricating Oils, Fats and Greases."

Analysis of Lubricating Greases

The method given by P. H. Conradson* is generally recommended and is essentially as follows:

1. Place 10 grams grease in a 300-c.c. wide-necked Erlenmeyer flask, add 50 to 75 c.c. 88° Bé gasoline and disintegrate with glass rod. Add 200 c.c. more gasoline, shake at intervals, settle, and pour off clear liquid through filter. Repeat treatment on residue, using 100 to 125 c.c. 88° Bé gasoline, transfer insoluble portion to large filter, let drain, rinse out flask with gasoline, and wash filter contents until gasoline passes through colorless. Let drain.

2. *Grease Oils*: — Evaporate mixed gasoline extracts to small bulk in tin drinking-cup, transfer to weighed beaker, and evaporate on water-bath to constant weight.

3. *Tarry Matter*: — If insoluble portion on filter has a light color (no asphalt or tar), it is transferred to a weighed dish and dried to constant weight (*see* 4). Otherwise, if dark from tarry matter insoluble in gasoline, it is replaced in flask and digested with 20 c.c. ethyl ether and 10 c.c. chloroform at ordinary temperature. Shake, transfer back to filter, and wash with ether-chloroform mixture. Evaporate extract in weighed dish on water-bath to obtain tarry matter with possible traces of soap.

4. *Insoluble Soaps and Mineral Matter*: — The insoluble residue from ether-chloroform treatment in No. 3 (or the insoluble light-colored portion from No. 1) is dried in a weighed dish, first at a low temperature on top of air-bath, and later, inside with gradual rise from 200 to 250° C., until constant weight is obtained.

5. *Water or Moisture (by Difference)*: — One hundred minus the sum of the insoluble soaps, mineral matter,

* Jour. Amer. Chem. Soc., June, 1904, p. 705.

tarry matter (if present), and oils gives the amount of moisture together with any trace of volatile substance.

6, 7, and 8. *Mineral Matter*: — When present in large amounts, it is easily noted as a heavy sediment on treatment with gasoline. Small amounts of mineral matter may be due to slaked lime and soda used in compounding.

To dissolve all soaps, fats, and oils, treat 5 grams of the grease separately with "100 c.c. of a mixture of 30 c.c. turpentine, 30 c.c. 74° Bé benzine, and 70 c.c. alcohol," using flask with reflux condenser on water-bath.

Filter liquid rapidly, and wash residue twice (hot) with above mixture, followed by benzine and alcohol. Dry, then weigh, and test character of residue.

9 and 10. *Bases in Soaps*: — In absence of free mineral matter, resort to 4, obtaining bases from dry soaps by ignition. Otherwise, heat the above filtrate and benzine-alcohol washings in a flask with reflux condenser on water-bath till clear. Add 2 or 3 grams oxalic acid dissolved in alcohol, boil and shake to form insoluble oxalates from which the oxides may be determined by usual methods.

11 to 16. *Remarks*: — Separated oils may contain little Ca and Mg soaps, soluble in gasoline in which Na soaps are insoluble. Zn, Al, and Pb soaps are rarely present, though soluble in gasoline. Determine bases by oxalic acid method and calculate to oleic acid. Separated oils should be saponified to separate free fatty oil from petroleum and rosin oils.*

FREE FATTY ACIDS, CAUSTIC AND CARBONATED ALKALI IN GREASES

Free Fatty Acids: — The weighed gasoline extract of the oils is placed in a flask with 50 c.c. neutral 95 per cent alcohol and a few drops phenol-phthalein indicator, and

* For further details see Conradson's article

titrated with N/10 caustic potash solution, from which the amount of free fatty acids may be calculated as oleic acid and deducted from weight of oils.

For Caustic: — Extract 5–10 grams of the grease with gasoline and treat the insoluble residue, after drying, with 50 to 100 c.c. of neutral 95 per cent alcohol, until the soaps are dissolved. Filter and wash with neutral alcohol. Add phenol-phthalein indicator and titrate with N/10 HCl for caustic.

For Carbonated Alkali: — The insoluble residue from alcohol is treated with water, methyl-orange indicator added, and the solution titrated with N/10 HCl for carbonate.

Free caustic lime may also be present from lime soaps.

SEPARATION OF FREE FATTY OIL, MINERAL AND ROSIN OIL

1. *Saponify Fatty Oils with Alcoholic Potash:* — Evaporate the alcohol and take up with water. Place soapy liquid in separator and treat with gasoline to remove mineral and rosin oils. Draw off gasoline layer and evaporate to obtain extract. Weigh the extract.

2. *Mineral and Rosin-oil Extract:* — Treat with glacial acetic acid to remove rosin oil, the mineral oil being insoluble. Use a conical separator and repeat the operation. Then wash the mineral oil with slightly alkaline water to remove excess acetic acid. Separate the mineral oil from aqueous portion with gasoline, evaporate, dry, and weigh. Subtract from total extract to obtain rosin oil by difference.

ROSIN OIL IN GREASE

Digest 10 grams grease in a wide-necked flask with 25 c.c. strong alcohol at gentle heat (water-bath). This should dissolve the ordinary soaps and rosin oil, with small amounts

of mineral oil or free fatty oil. Break up grease with glass rod, shake, settle, pour off liquid on dry filter, and repeat treatment with 25 c.c. more alcohol.*

To the combined alcoholic filtrates, add a little phenolphthalein indicator, and slight excess N/4 caustic potash, to saponify any free fatty oil. Evaporate to expel alcohol; treat residue with 25 to 30 c.c. gasoline; stir, settle, filter clear fluid, and evaporate gasoline.

The residue contains most of the rosin oil, together with a little mineral oil. Note odor, taste, and gravity. Test for rosin oil by the Liebermann-Storch reaction.

* Note Conradson's article, Jour. Amer. Chem. Soc., June, 1904, pp. 711-712.

LINSEED OIL (from Flaxseed)

Raw linseed oil should have a clear amber color and sweet syrupy odor, in distinction from the darker boiled product.

It should be free from "foots" through long standing before use. The oil contains chiefly the glycerides of certain unsaturated fatty acids—oleic, linolic, linolenic, and isolinolenic—forming the original "linoleic acid" investigated by Hazura.* Walnut oil contains the same glycerides as linseed, while poppy, sunflower, and hemp-seed oils consist mainly of the glyceride of linolic acid.

Unsaturated series of fatty acids may be represented by the following formulæ:

Series, $C_nH_{2n-2}O_2$, or $C_{18}H_{34}O_2$, Oleic Acid.

Series, $C_nH_{2n-4}O_2$, or $C_{18}H_{32}O_2$, Linolic Acid.

Series, $C_nH_{2n-6}O_2$, or $C_{18}H_{30}O_2$, Linolenic Acid.

When fatty acids of the above type are dissolved in glacial acetic acid and ether, and treated with bromine, certain addition products are formed, thus:

$C_{18}H_{34}.Br_2.O_2$, oleic acid "di-bromide" (liquid).

$C_{18}H_{32}.Br_4.O_2$, linolic acid "tetra-bromide," M. P. $114^{\circ}C$.

$C_{18}H_{30}.Br_6.O_2$, linolenic acid "hexa-bromide," M. P. $177^{\circ}C$.

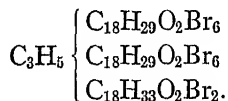
The insoluble crystalline hexa-bromide, on treatment with zinc dust in alcoholic hydrochloric acid solution, loses Br_6 , reproducing linolenic acid, from which the same hexa-bromide may again be derived.†

With oils direct, as linseed and various fish oils, a "mixed bromo-ester" is formed, more insoluble than the acid hexa-bromide and possessing a di-bromo and hexa-bromo combi-

* Andes, *Drying Oils, Boiled Oils, etc.*, 1901, p. 7.

† Wright, *Oils, Fats, Waxes, etc.*, 1894, pp. 27, 35, and 36.

nation without the tetra, and to which Hehner and Mitchell* have given the tentative formula:



An insoluble precipitate. M. P. 143.5 to 144° C.

Oxidized or boiled oils produce little or no precipitate.

Iodine also forms addition-products, hence the Hübl method for determining iodine absorption.

ADULTERANTS OF LINSEED OIL

Fish oil (menhaden) itself possesses drying properties and is least harmful of the possible adulterants. The fish oil likewise is subject to adulteration with mineral oil.

Fish oil may be recognized by its odor on heating; by the reddish color produced on boiling with caustic soda, and by the dark greenish color imparted when chlorine is passed through fish oils.

Menhaden has almost the same specific gravity as linseed, viz., 0.930–0.932 at 15° C. Mineral oils have a lower gravity (0.903), while rosin oils (about 0.985) increase the gravity.

Mineral oil or petroleum forms a very cheap adulterant for linseed, but retards drying and in large amount may cause “sweating” and decomposition of paint coating.

Water may be incorporated with linseed oil in the form of an emulsion by adding glue, sugar of lead, carbonate of soda, silicate of soda, borax, etc., for cheap “barn paints” containing iron reds and ochres.†

Mineral oil, being non-saponifiable, may be separated by saponifying other oils and then extracting with gasoline or petroleic ether.

* Analyst, 1898, p. 317.

† Hoff, Paint and Varnish Facts and Formulae, 1905, p. 76.

A dark color in itself does not signify adulteration, and a slight "fishy" odor does not necessarily indicate the presence of a fish oil, but may be due to the method of heating, temperature, driers, etc.

Hempseed oil is a frequent constituent of linseed oil from admixture in original seeds. Hempseed oil gives a pasty green soap with caustic potash, while the soap from linseed is usually dark brown. Hempseed produces a greenish coloration with concentrated hydrochloric acid, while pure linseed gives a yellow color.

Rosin oil would impart more or less "bloom" and pitchy odor, increase viscosity and gravity, give low saponification value, low bromine addition, and high bromine substitution figures. Mineral oil would reduce all the constants.

IMPORTANT TESTS ON LINSEED OIL

Specific Gravity: —

Sp. gr. of raw linseed oil, 0.931 to 0.937 at 15.5° C.

Sp. gr. of boiled linseed oil, 0.931 to 0.950 at 15.5° C.

Lowered by cottonseed oil. (Sp. gr. 0.922–0.930 at 15.5° C.)

Lowered by corn oil. (Sp. gr. about 0.924 at 15.5° C.)

Lowered by mineral oil. (Sp. gr. 0.850–0.925 at 15.5° C.)

Increased by rosin oil. (Sp. gr. 0.970–1.000 at 15.5° C.)

Unchanged by menhaden oil. (Sp. gr. about 0.930 at 15.5° C.)

Volatile Oil or Thinner (Turpentine or Benzine): —

Obtained by distillation with steam (McIlhiney's Process), then collected, measured or weighed. Benzine is separated from turpentine by allowing a measured quantity to fall, drop by drop, upon fuming nitric acid in a flask fitted with reflux condenser, and cooled, whereby the turpentine is destroyed. Benzine, unaffected, is washed in a separation funnel and measured.

Acid Figure: — Expressed in milligrams KHO per gram oil should be less than 5.* Increased by rosin; also by mineral acids used in refining. 5 to 10 grams oil are heated with alcohol neutral to phenol-phthalein, shaken and titrated with N/2 KHO.

Koettstorfer Figure: — Should not be less than 186 nor higher than 196 for either raw or boiled oil. Figure lowered by mineral oil, rosin oil, or turpentine.

Unsaponifiable Non-volatile Matter: — Should be less than 2.5 per cent. Any mineral or rosin oil present may be extracted from saponified oil with ether; the extracted oils are weighed, then heated with nitric acid (sp. gr. 1.2) to convert rosin oil to a resinous mass which is treated with petroleic-ether to remove any mineral oil.

Livache Drying Test: — Action of finely precipitated lead on film of oil in a watch-glass. Weight increased by absorption of oxygen; greater with linseed than with menhaden oil.

Maumené Test: — Rise of temperature with sulphuric acid is greater with menhaden than linseed oil.

Bromine absorption and substitution figures and hexabromide test as described.

BROMINE ABSORPTION METHOD

Besides addition products, bromine also forms substitution products — slight with seed oils, but pronounced with turpentine, rosin, and rosin oils — through replacement of hydrogen.

According to McIlhiney, the Hübl iodine process fails to distinguish between addition and substitution of halogen.† Hence, the "Bromine Substitution Figure," advo-

* McIlhiney — Sabin's Technology of Paint and Varnish, 1904, p. 56.

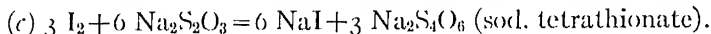
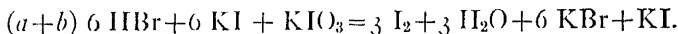
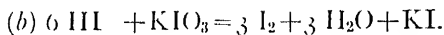
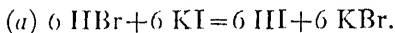
† Sabin's Technology of Paint and Varnish.

cated by McIlhiney, affords a valuable means of indicating adulterations of the oil sample with above substances.

Outline of McIlhiney's Bromine Method:—Place 0.2 gram oil, 10 c.c. carbon tetrachloride, and 20 c.c. N/3 bromine in CCl_4 (by pipette) in a dry glass-stoppered bottle.

Pipette a separate 20 c.c. N/3 bromine in CCl_4 into a similar glass-stoppered bottle for a blank test.

Cool the bottles. Reaction is nearly instantaneous (few minutes). Slip piece of rubber tubing over neck of bottle. Introduce 25 c.c. neutral 10 per cent potassium iodide solution, pouring iodide solution into "well" formed by tubing and lifting stopper slightly to allow solution to be sucked into cooled bottle, thus preventing loss of bromine and hydrobromic acid. Shake, place on ice a few minutes, since heat of reaction might cause expansion and loss of vapors. Titrate free iodine with neutral N/10 sodium thiosulphate (using little starch indicator) for the total amount of bromine absorbed. Next add 5 c.c. neutral 2 per cent potassium iodate (KIO_3) solution with little more starch indicator, and titrate the liberated iodine, equivalent to the hydrobromic acid produced in the original reaction.



1 c.c. N/10 $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5 \text{ H}_2\text{O}$, or 0.02480 gram thiosulphate,
is equivalent to 0.01265 gram iodine,
or equivalent to 0.00800 gram bromine.

Regarding the foregoing reactions, experiment shows that KIO_3 reacts with HBr to liberate bromine in solution, and that on adding a solution of KI a separation of

solid iodine takes place, which is soluble in an excess of KI and CCl_4 .

KI and KIO_3 show no reaction with each other.

The formation of HI from solid KI and concentrated HBr is hardly apparent in the cold, yet the transposition evidently takes place on heating, since the white solid deposited on cooling and after washing with 90 per cent alcohol gives tests for bromide with dilute sulphuric acid and potassium bichromate as shown by the liberation of bromine and absence of the iodine color test with chloroform. Likewise, the acid solution gives a pronounced test for iodine and little or no bromine. Similar tests also indicate that in cold dilute solutions of KI and HBr the production of HI is slow, partial, or incomplete, and that the addition of an oxidizing agent like KIO_3 is essential.

To obtain the "Bromine Addition Figure," subtract twice the "Bromine Substitution Figure" from the total bromine absorption, for just as much more bromine is required to form hydrobromic acid as is required to substitute hydrogen in the "fatty chain" of the oil sample.

McIlhiney* prefers the bromine method to the Hübl process, because the former is quicker and the standard solution, unlike the Hübl solution, does not deteriorate on keeping if properly closed; that is, it is always ready and there is no delay in action of the reagents.

Bromine addition figure for raw or boiled oil, 100 to 110.

Bromine substitution figure for raw or boiled oil, 3 to 5.

The substitution figure is increased by turpentine, rosin, and rosin oil, which have figures varying from 20 to 90. The addition figure is lowered by rosin, rosin oil, benzine, and mineral oils, which have figures lower than 15. The

* Sabin's Technology of Paint and Varnish, 1904, pp. 47-51; also Drugs, Oils, and Paints, Phila., Aug., 1901, p. 90.

addition figure for turpentine is higher than 110; corn oil, 73; and cottonseed oil, 63.

BOILED LINSEED OIL

Boiled oil, produced by heating with litharge and other drying agents, is generally much darker than raw oil, especially if small amounts of manganese are present.

The object of boiling seems to be the coagulation of slimy or mucilaginous matter, which settles out on standing, thus clarifying the oil, and the presence of which might affect the drying properties.

According to the method of boiling and treatment, various grades are obtained which may differ considerably in their chemical constants.

The oil should be clear and of a light color, especially if it is to be employed with light-colored pigments.

Long continued boiling at an elevated temperature simply results in "cracking up" the glycerides and producing a darker colored oil, especially if manganese be present.

For paint purposes the oil should not be heated above 180° to 200° C., and then only for a short period to drive out moisture, introducing the driers after first removing from the fire.

Thickened linseed oil of a light color may be prepared by heating with driers in a current of hot air, at a temperature of 100° C. (more or less), using agitation or spraying apparatus according to method desired. The thickened oil may be dried in layers on cheese-cloth, forming an elastic yellow linoleum product which serves when kneaded with cork or sawdust for the manufacture of linoleum.

"Burnt" linseed oil, such as used for printer's ink, is made by heating the oil for several hours at an elevated temperature (360° to 380° C.) until it becomes thick, stringy, and

sticky. It has a "scorched" odor and a dark color due to partial decomposition and separation of finely divided particles of carbon.

Varnishes, Japan driers, etc., are usually composite mixtures of boiled oil, gum resins, rosin (colophony), oleates, linoleates, and resinates of lead and manganese, with or without thinners as turpentine or benzine. Spirit varnishes are made by dissolving shellac, rosin, sandarac, mastic, benzoin, etc., in alcohol or turpentine.

Pyroxylin varnishes usually contain amyl acetate.

PROPORTION OF DRIERS

The proportion of mixed driers in boiled linseed oil is generally small, the total mixed oxides (PbO and MnO) obtained by analysis rarely exceeding 0.25 per cent ($\frac{1}{4}$ of 1 per cent) of the oil sample — equivalent to about 1.5 per cent to 3 per cent in the form of soluble resinate or linoleate.

The PbO is usually in excess of the MnO in a ratio varying from 3 : 1 to 5 : 1.

Fused resinate of lead, as prepared by the author, contains about 9 per cent PbO, and resinate of manganese about 6 per cent MnO — each having an excess of rosin, thus approximating formulæ given by Andes.

To form a ratio of 3 PbO : 1 MnO with above resinates, a mixture of 2 parts of the lead resinate with one part of manganese resinate would be necessary in which the mixed oxides would average 8 per cent — this constituting the 0.25 per cent of the oil sample.

Thus:

Resinate (PbO, 9 per cent), 2 parts, 18 per cent PbO.

Resinate (MnO, 6 per cent), 1 part, 6 per cent MnO.

3 parts) 24 per cent total.

8 per cent average
mixed oxides.

Now, if 0.25 per cent represents 8 per cent mixed oxides in resinate added, then the equivalent of resinate, as such, would be found by the proportion $0.25 : x :: 8 : 100$, where x equals 3.12 per cent resinate in oil.

Referring to Amsel,* pure resinsates of lead and manganese should contain amounts of lead and manganese which would be equivalent to about 25 per cent PbO and 8 per cent MnO respectively; but the metallic content is often lower depending on the amount of rosin present, combined and uncombined.

According to Andes,† the linoleates contain similar amounts of the metals in combination.

To obtain a ratio of 5 PbO : 1 MnO from these percentages, it would be necessary to use 5 parts of the lead compound with 3 parts of the manganese compound, thus:

Resinate (PbO, 25 per cent),	5 parts,	125 per cent PbO.
Resinate (MnO, 8 per cent),	3 parts,	24 per cent MnO.
	8 parts	) 149 per cent total.
		18.6 per cent average mixed oxides.

Now, if 18.6 per cent *mixed oxides* in the resinate (or linoleate) employed constitute 0.25 per cent ($\frac{1}{4}$ of 1 per cent) of the oil sample, then its equivalent in metallic linoleate or resinate, as such dissolved in the oil, would be indicated by the following proportion $0.25 : x :: 18.6 : 100$, where x equals 1.34 per cent resinate or linoleate as the case may be. That is, the metallic resinate or linoleate existing as drier in the oil will probably average less than 3 per cent in the sample. However, certain liquid driers and oil varnishes may contain higher percentages.

In producing "boiled oil" the driers (either as mixed

* Analyst, 1896, p. 261.

† Drying Oils, etc., 1901, p. 163.

resinates or a mixture of litharge and manganese resinate) may first be dissolved in a small quantity of oil heated to 180°C. , and this in turn incorporated with a larger body of oil at a lower temperature (100°C.). Or, the metallic oxides as such may be heated directly with a small quantity of oil at 250°C. to 300°C. , forming a dark liquid, which may be stirred into the main body of oil at a lower temperature (100°C.), thus forming a paler product. Or, a solution of manganese resinate in hot turpentine (1 part of resinate in 4 parts turps) may be prepared over a steam-bath and, after stirring until dissolved, cooling, settling, and filtering, it may be added cold in small amounts to the raw oil as needed. Various other methods may be employed by the manufacturer; but, at low temperatures (40°C.), only soluble or liquid driers should be employed, since metallic oxides require higher temperatures with a corresponding darkening of the oil.

High percentages of linoleate or resinate tend to produce excessive amounts of "foots" and separation of drier without increasing drying properties of the oil. In fact, the writer ascertained by experiment that hot linseed oil (180°C.) would not take up more than a small amount of prepared linoleates of lead or manganese, the rest being insoluble or separating on cooling. Again, a mixture of manganese resinate and lead linoleate exhibited a better drying action than a mixture of corresponding linoleates.

DETERMINATION OF DRIERS IN OIL

Incinerate 5 grams of the oil sample in a small porcelain dish under a hood or in a well-ventilated place.

Treat the residue or ash with hot dilute hydrochloric acid (1 : 1) — odor of chlorine indicates manganese — filter hot, and wash. To filtrate add a little sulphuric acid and evaporate to fumes, forming PbSO_4 , which is washed.

dried, and weighed on a tared filter. The presence of small amounts of siliceous matter from the ash may be ignored; but if desirable, the PbSO_4 may be dissolved out with hot ammonium acetate solution — leaving SiO_2 , etc., behind — and the filter rewashed, dried, and weighed again to determine PbSO_4 by loss. Calculate to PbO . Or, the PbSO_4 may be reprecipitated from the cold ammonium acetate solution by adding dilute sulphuric acid and about 10 per cent alcohol, filtering and washing with 1 per cent dilute sulphuric acid followed by strong alcohol.* Or, the cold ammonium acetate solution may be slightly acidified with acetic acid, the lead precipitated with a moderate excess of standard potassium bichromate solution, the PbCrO_4 thus formed being filtered and washed, and the excess of bichromate in the filtrate and washings titrated with standard sodium thiosulphate solution.† A blank titration on the amount of bichromate employed gives the difference from which the amount of PbO may be calculated.

For manganese, the original acid solution containing washings — from treatment of ash residue for lead — is boiled with a little hydrochloric acid and a slight excess of ammonium hydrate to remove iron and alumina if present. Filter, concentrate, add little acetic acid and bromine, and heat to precipitate manganese. Ignite and weigh as Mn_2O_4 . Calculate to MnO .

PAINT ANALYSIS

Turpentine, Benzine, Gasoline Thinner, etc.:—Weigh from 50 to 100 grams paint in a counterpoised round litre flask, containing a little water to prevent paint from adhering to the bottom, connect with condenser, and distil with steam.

* Miller, Quant. Anal., 1907, p. 105.

† *See also* — *Miller*, *ibid.*

Transfer distillate to graduated stop-cock cylinder, read off turpentine, benzine, or gasoline layer, separate from water, and determine specific gravity. In presence of benzine, the turpentine may be destroyed by means of nitric acid.*

Pigment: — Weigh 25 grams mixed paint in a 500-c.c. Erlenmeyer flask, add 200 to 300 c.c. gasoline, shake, lay on side, settle over night, filter, repeat operation, and reserve gasoline filtrates for oil. A more rapid extraction has been proposed by Keeler,† who uses a Gooch suction filter, packed with a heavy bed of fine asbestos.

The pigment may contain yellow ochre as $\text{Fe}_2(\text{OH})_6$, clay body, etc.; iron reds (Fe_2O_3); umbers and siennas (Fe_2O_3 , MnO_2 , clay, etc.); gypsum (CaSO_4); barytes (BaSO_4); lead sulphate (PbSO_4); white lead (PbO_2H_2 , 2 PbCO_3); zinc white (ZnO); whiting (CaCO_3); witherite (BaCO_3); chrome yellow (PbCrO_4); chrome green (Cr_2O_3); Paris green as $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$, 3 $\text{CuO} \cdot \text{As}_2\text{O}_3$; Prussian blue as $\text{Fe}_4(\text{FeC}\text{N}_6)_3$; ultramarine blue as $(\text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8)_4 \cdot \text{Na}_2\text{S}_4$; carbon black, lampblack, graphite (C); silica (SiO_2); red lead (Pb_3O_4); antimony red (Sb_2OS_2); vermilion (HgS); vermillionettes (eosin-tinted pigments); carmine lake, etc. First, make qualitative tests, then construct a scheme for quantitative separation. Use dilute acetic acid to separate white lead, zinc white, whiting, witherite, etc., from insoluble sulphate, PbSO_4 , BaSO_4 , CaSO_4 , SiO_2 , clay, etc.‡ Digestion of the residue with ammonium carbonate converts PbSO_4 and CaSO_4 into carbonates which may be dissolved out with dilute acetic acid, leaving BaSO_4 , SiO_2 , clay, etc., unaltered. If CaSO_4 is present, then $\text{PbO}_2\text{H}_2 \cdot 2 \text{PbCO}_3$ on treatment with dilute acetic acid produces a precipitate of PbSO_4 ,

* Phillips' Engineering Chemistry.

† Jour. Ind. and Eng. Chem., September, 1910, p. 388.

‡ See also Quantitative Analysis.

not originally present. Note also that PbSO_4 is soluble in hot ammonium acetate, as a separation from BaSO_4 , insoluble, and from CaSO_4 and SiO_2 . After extraction of oil, the pigment usually retains some insoluble gummy matter or dried linoleate, which may be dissolved or removed with weak caustic potash before attempting examination or separation of mineral contents.

Oil Extract (Gasoline Filtrates): — Evaporate gasoline filtrates in a weighed beaker over a steam-bath. Weigh total residue and drier.

Driers: — Incinerate 5 grams oil and test ash; or, transfer the oil extract to a separation funnel, shake well with dilute HCl , repeat, combine HCl solutions, evaporate and test for lead and manganese. Note that white-lead and red-lead pigments exert drying action on oil independently of added drier, and may retain some Pb soap combination.

INSOLUBLE SOAPS (SO-CALLED)

Oleates, stearates, and palmitates of the alkalis — K_2O , Na_2O , etc., — are known as soluble soaps; that is, they are soluble in water. Soda soaps are insoluble in brine.

Oleates, stearates, and palmitates of the alkaline earths — CaO , BaO , MgO , etc. — and also of the heavy metals — Pb , Cu , Fe , Zn , etc. — are soaps, insoluble in water.

Soaps insoluble in water do not have potash or soda bases. Thus, a lime soap may be formed when ordinary soap is dissolved in hard water, the insoluble soap being precipitated as a "scum." Likewise, when a fat is saponified with hydrated lime, the resulting oleate or stearate is quite insoluble and does not produce a "lather." The barium and strontium soaps are similar.

solved in sea-water, hence the use of specially prepared "marine soaps," more or less soluble in salt water, and made from cocoanut or palm oils.

Aluminum soap is one of the principal insoluble soaps, generally precipitated with aluminum acetate or sulphate. Alumina (Al_2O_3) does not saponify fats, but if sodium or potassium aluminate is used, then the aluminum soap is formed.

Materials may be waterproofed by treatment with aluminum acetate followed by soap solution.

Goods may be mordanted with aluminum salts, colored or dyed, and pressed with soap solution, whereby aluminum oleate is formed, thus fixing the color.

Zinc soap may be formed by double decomposition of zinc sulphate and soda soap, forming yellowish-white masses easily dried, or it may be formed directly by heating zinc white with olive oil, yielding "zinc plaster."

Lead soap, or "lead plaster," is a yellowish-white plastic mass formed by decomposition of a soluble soap with lead acetate, or by heating litharge with olive oil.

Tin soap, prepared from a soluble soap by precipitation with tin protochloride, has been used as a mordant for certain vegetable dyes.

Copper soap, obtained by precipitating a soap solution with blue vitriol, is a greenish mass, which, when dry, is readily soluble in alcohol, ether, and oils.

Iron soap (the most peculiar of all) as the oleate is a slimy, dark-red pasty mass, having a strong metallic odor and may be precipitated from a soap solution either with neutral ferric chloride or with ferrous sulphate (iron vitriol). Iron stearate, from sodium stearate and iron salt, is a brown granular mass with slight odor. Precipitations should be made from hot solutions.

Copper and iron soaps, when dry, are soluble in fat

turpentine, and, if properly incorporated with varnish oil and turpentine drier (Japan drier or resinate), should produce desirable stains or coatings for shingles or plaster casts.

Oleates of fair quality may be prepared from hot aqueous solutions of castile soap by diluting and adding the requisite quantity of a neutral solution of the chloride or sulphate of the desired metal. In this manner, the oleates of Zn, Al, Fe, Pb, Cu, Ba, Ca, etc., are readily obtained, all more or less soluble in ether or turpentine.

Stearates and palmitates may be derived from stearic acid or palm oil by saponifying and precipitating with metallic solutions in the usual manner. Special methods with alcoholic solutions are employed to separate stearates from palmitates or oleates, depending on the use of lead and magnesium salts.

Lead stearate may be produced directly by "double decomposition" from potassium stearate in alcoholic solution, thereby eliminating oleate.*

The palmitates resemble the corresponding stearates.

As to soluble soaps, the soft potassium compounds are more soluble than the hard sodium compounds, both forming, when concentrated, jelly-like solutions with water. Mixed with alcohol the aqueous gelatinous soap is known as "opodeldoc."

Lead Oleate, $\text{Pb}(\text{C}_{18}\text{H}_{33}\text{O}_2)_2$, is the main ingredient of medicinal "lead plaster," derived directly by heating litharge and olive oil. It may also be prepared from sodium oleate by "double decomposition" with lead acetate in a hot aqueous solution, forming a cream-white precipitate which dries in air to a white powder and melts at 80°C. to a yellow oil, which on cooling solidifies to a translucent body. Soluble in alcohol, ether, turpentine, and petroleic ether; ordinary soaps are practically insoluble in petroleic

* See Lead Stearate

ether. Its solubility in ether distinguishes it from lead stearate and palmitate.

Lead Stearate, $\text{Pb}(\text{C}_{18}\text{H}_{35}\text{O}_2)_2$, prepared by "double decomposition" from potassium stearate and lead acetate, preferably in alcoholic solution, yields, after drying in the air, a white powder melting at 125°C . After melting, it cools to an opaque mass. Insoluble in alcohol, ether and petrolic ether in distinction from lead oleate, linolate, or ricinolate.*

Lead Palmitate, $\text{Pb}(\text{C}_{16}\text{H}_{31}\text{O}_2)_2$, is similar to the stearate, in solubility, but its melting-point is lower, from 108°C . to 112°C . Generally, the palmitates are more soluble in alcohol, especially in presence of acetic acid, than the corresponding stearates.

Aluminum Oleate, $\text{Al}(\text{C}_{18}\text{H}_{33}\text{O}_2)_3$, well-known as an oil "thickener," may be derived from sodium oleate by precipitation with aluminum sulphate in hot aqueous solution. The wet precipitate is cream-white, sticky, plastic, and more or less elastic. It may be dried by melting down over a low flame — on an enameled plate — yielding a translucent, brown, elastic, viscous mass.

Aluminum Palmitate, $\text{Al}(\text{C}_{16}\text{H}_{31}\text{O}_2)_3$,† is stated to be an elastic amorphous mass, soluble in turpentine and petrolic ether, forming a viscid varnish, which, on evaporation, forms an elastic, odorless film impervious to water.

For Insoluble Linoleates: First prepare soluble sodium (or potassium) linoleate, from which the other metallic linoleates may be derived, thus:‡

Raw linseed oil	10 oz. (approx. 280 grams).
Caustic soda	1.5 oz. (approx. 40 grams).
Water	25 oz. (approx. 700 grams).

* See Allen, Vol. II, pt. 1, pp. 256-257.

† J.S.C.I., 1882, p. 278.

‡ For comparison, see Andes, Drying Oils, Boiled Oils, etc., 1901, p. 200.

Heat to boiling in agate-ware kettle, frequently stirring with a broad spatula. Continue boiling, occasionally adding water to compensate for evaporation, until the mass becomes stringy or "ropy" on spatula.

The caustic alkali should be slightly in excess of the theoretical amount, thereby tending to promote a more rapid saponification.

Time required: two hours or longer.

On cooling slowly, the mixture should approach a jelly-like consistency.

If caustic potash lye be employed, the sodium compound may be obtained by "salting out," since sodium soaps are insoluble in brine.

The soapy mass of sodium linoleate is quite soluble in pure water, and from the solution, preferably hot, various insoluble metallic soaps may be derived by simple precipitation with the corresponding metallic salt.

Manganese Linoleate: — This is precipitated from a hot solution of linseed oil soap (sodium linoleate) by adding a hot solution of manganese chloride, $\text{MnCl}_2 \cdot 4 \text{H}_2\text{O}$ — about 20 per cent strength — until the linoleate is completely separated, using about two-thirds as much manganese salt by weight as linseed oil soap in solution. Wash the slimy, pasty mass by decantation with hot water, and, if necessary, melt over low flame on enameled plate to a dark-brown translucent elastic mass.

Lead Linoleate: — This is derived easily from a hot solution of linseed oil soap, using a solution of lead acetate as the reagent. The lead linoleate, which separates as a curdy, white mass, should be washed by decantation with hot water, then filtered, dried, and melted on an enameled pan to a yellowish translucent mass. It is soluble in warm turpentine. Alone, its drying action on raw linseed oil is very slow, but is quickened by presence of very small

amounts of manganese compound and sufficient turpentine.

Lead-manganese Linoleate: — A fused mixture of three parts lead linoleate and one part manganese linoleate — much used as a drying medium. When dissolved in turpentine or hot linseed oil and “run into” various melted gums and “thinned” with turpentine, it forms a liquid “drier” or varnish.

In preparing boiled linseed oil with linoleate driers the oil is usually heated to 180°C ., or above, to drive out moisture and clarify; then the mixed linoleates (3 per cent to 5 per cent), previously dissolved in a little oil, are incorporated.

According to the writer's experience, the metallic resinates seem to possess more active drying properties than the corresponding linoleates, and a combined resinate and linoleate is apparently better than either alone, as, for instance, lead linoleate and manganese resinate in suitable proportions.

The metallic resinates may be derived either by precipitation or by fusion of the constituents.

To form resinates by precipitation it is first necessary to prepare a rosin soap or resinate of soda, as follows:

Rosin Soap (Resinate of Soda): —

Use a large agate-ware kettle.

160 parts water.....	8 lbs.
100 parts common rosin.....	5 lbs.
20 parts dry soda ash.....	1 lb.

Heat the water and soda ash (dry carbonate) together, and add rosin in small lumps.

The rosin combines with the soda, driving out the CO_2 and producing froth.

Neutralize by adding more rosin or soda as may be

required, until the frothing subsides, and continue boiling until solution becomes clear brown, occasionally adding hot water to make up loss by evaporation.

The operation may require one or two hours.

Other Formule: —

100 parts water	5 lbs.
100 parts common rosin	5 lbs.
100 parts washing soda, $\text{Na}_2\text{SO}_4 \cdot 24 \text{ H}_2\text{O}$. . .	5 lbs.

or

160 parts water	8 lbs.
100 parts common rosin	5 lbs.
15 parts caustic soda (NaOH)	$\frac{3}{4}$ lb.

Lead Resinate by Precipitation: — Take a boiling hot solution of rosin soap, dilute it somewhat, and stir in slowly a moderate quantity of saturated lead acetate or sugar of lead solution until the mass coagulates or separates into white curdy lumps.

Decant the aqueous portion, add more hot water, and wash on a ribbed filter. Spread out same to dry on porous brick or tile. It dries to a cream-white pulverulent powder, which is soluble in warm turpentine.

The resinate may be incorporated with hot linseed oil at 130°C ., in moderate amounts, the material dissolving in the oil as fast as any residual moisture "fries out."

Manganese Resinate by Precipitation: — Start with a boiling hot solution of rosin soap, and add in a thin stream a moderately concentrated solution of manganese chloride ($\text{MnCl}_2 \cdot 4 \text{ H}_2\text{O}$) with constant stirring until the mass curdles or separates.

Decant, wash by adding more hot water, and collect on a ribbed filter. Spread out to dry on warm brick or tile. If necessary, the dried material may be melted or fused on a flat enameled dish at a gentle heat, when it becomes darker.

Lead Resinate by Fusion: — Melted rosin will take up from 10 per cent to 20 per cent of litharge in combination, forming a clear product of resinate of lead very similar in appearance to the original rosin.

Perform the operation in an agate-ware or iron pot of three or four times greater capacity than the bulk of material to be prepared — to preclude the possibility of frothing over. This should be done over a low fire or flat burner.

For example, first melt common rosin, 9 parts by weight. Then stirring with spatula, gradually add litharge powder, 1 part by weight. When the fusion is complete and the melted liquid runs off the spatula clear, allow to cool by standing; and when thoroughly cold and solid, invert the pot on a sheet of paper spread on the floor. Then by knocking or slamming the pot on the paper, the brittle mass cracks or becomes loosened and falls out.

Lead resinate is quite soluble in hot turpentine. Alone, without manganese, it imparts very little drying action to linseed oil.

Manganese Resinate by Fusion: — Use the pure manganese hydrate. Ordinary black oxide or peroxide of manganese is too hard and does not fuse properly with melted rosin.

Manganese hydrate. 1 part by weight.

Common rosin 9 parts by weight.

Melt the rosin first in a deep agate-ware pot over a moderate heat or flat burner. Then, gradually add the finely powdered manganese hydrate, constantly stirring until frothing subsides.

The temperature should not be above 200° C. or 205° C., to avoid burning by rapid oxidation or overflow. Continue heating until the melt clarifies. Cool by standing; invert

the pot and remove the brittle mass by knocking on paper spread on the floor.

If properly done, there should not be any manganese residue on bottom of melt; if any, it should be slight. The color of the product is somewhat darker than the original rosin.

It is quite soluble in hot turpentine in the proportion of 1 : 4 by weight, giving, on digesting over a steam-bath and cooling by standing, a clear wine-colored fluid or liquid "drier," quite active with raw linseed oil.

For Luster Work on Glass

Solutions of various metallic resins in lavender oil or turpentine have been proposed.

Lead Resinate: — Melt together

Lead acetate ("sugar of lead") 1 weight

Common rosin 3 weights

Cool, crush, and dissolve in warm turpentine.

Copper Resinate: — Add a solution of copper sulphate to a hot rosin-soap solution. Wash the precipitate of copper resinate on a filter, dry at a moderate temperature, and dissolve in hot lavender oil or turpentine.

Iron Resinate: — Add ammonium carbonate to a solution of ferric chloride until a neutral red color is formed without precipitate. Then add the same to a hot solution of rosin soap. Collect the precipitate of iron resinate and wash on a ribbed filter. After drying dissolve in hot lavender oil or turpentine.

The oil solutions of the metallic resins are applied with a brush to the glass article which is then heated in a muffle, whereby the organic matter is destroyed, resulting in the formation of gases which exert a reducing action.

FATTY ACIDS

Mechanical Separation: — Since the fatty acids of the stearic series are solid at ordinary temperatures, while other series (as oleic, linolic, and ricinolic) are liquid, their separation may be effected by filter-pressing as in the case of solid or liquid fats.

Chemical Separation: — A general method for separating stearic acid and its homologues from oleic and other fatty acids is based on the fact that the *lead* compounds of the stearic series are almost insoluble in ether, while the corresponding compounds of the other fatty acids are soluble.

Soluble in Ether or Petrolie Ether: — Lead oleate, hypogeate, linolate, and ricinolate.

Insoluble in Ether or Petrolie Ether: — Lead arachidate, laurate, myristate, palmitate, and stearate.

Separation of Palmitic, Stearic, and Oleic Acids

Twitchell* recommends the use of petrolie ether, volatile at 80° C., in which lead stearate and palmitate are much less soluble than in ordinary ether. Therefore, saponify the sample with alcoholic KHO, add a drop of phenol-phthalein solution and then slowly, drop by drop, acetic acid until the pink color is just discharged.†

Filter the liquid, add twice its weight of ether, and then an alcoholic solution of lead acetate. Note that lead oleate is soluble in ether.

The white precipitate of stearate and palmitate of lead is filtered and washed with ether and then treated with dilute HCl in a hot aqueous solution. The liberated fatty acids are filtered and washed with hot water; then dissolved in boiling alcohol, and a hot alcoholic solution of magnesium

* J.S.C.I., 1895, 516.

† Allen, *Comm. Org. Anal.*, 1800. Vol. II. pt. 1. p. 262.

acetate added, when, on cooling, magnesium stearate should separate.*

Solubility in Alcohol:—

Magnesium stearate...insoluble cold; soluble in boiling alcohol.

Magnesium palmitate.soluble in alcohol.

Magnesium oleate....soluble in alcohol and petrolic ether.

Barium stearate.....moderately soluble in alcohol.

Barium palmitate....soluble in excess of alcohol.

Barium oleate.....difficultly soluble in boiling alcohol.

Each fatty acid, as such, may be derived from the corresponding oleate, stearate, and palmitate by decomposition with hot dilute HCl, the liberated fatty acid separating as an oily layer on top of the hot aqueous solution, from which it may be separated by filtration through a ribbed filter in a hot-water funnel or air-bath; or, if solid at ordinary temperatures, by chilling and decantation.

Palmitic acid may be easily obtained by saponifying spermaceti shavings with alcoholic KHO, using a reflux condenser, and precipitating with a saturated solution of barium chloride. The barium palmitate is collected on a Canton flannel filter, washed with hot alcohol, decomposed with hot dilute HCl, and the palmitic acid repeatedly chilled and washed with hot water, and finally purified by alcohol (by crystallizing).

It is well to note that the liberated fatty acids are all quite soluble in alcohol, in marked contrast to the glycerides or fatty oils or waxes from which they are derived.

Certain fatty acids of the lower series, such as acetic, butyric, capric, etc., are soluble in water or volatile with steam as distinguished from the higher fatty acids, waxes, or hydrocarbons insoluble in water.

* See Allen, 1899, Vol. II, pt. 1, pp. 241, 255, 263.

Determination of Melting-point

The melting-points of fatty acids, fats, etc., are not always constant for the same substance, depending on whether the material has been melted or remelted several times at or above its fusing point; whether cooled suddenly or slowly; whether its consistency is uniform or not.

To insure uniformity in melting-point tests, the fatty acids (or wax as the case may be) should be melted slightly above fusing-point to eliminate moisture and suspended matter, then drawn up into thin capillary tubes (about 4 inches long, made from glass tubing), and after chilling for an hour or more, one of these may be selected and attached with an elastic band to the bulb of a long-stemmed thermometer, graduated to $\frac{1}{5}^{\circ}$ C., inserted in cold water or oil bath, and the temperature gradually raised until the substance liquefies and rises in the tube.

Or, if desirable, the capillary tubes may first be sealed at one end and then contracted slightly, about $\frac{1}{2}$ inch, beyond the end by heating gently in the tip of a small flame, after which, the dry solid substance (in fragments or powder) may be introduced at the open end and shaken down and the melting-point determined by noting the temperature at which the solid melts and flows past the contraction in lower end.

The capillary should be adjusted by band so that the lower or sealed end is next to or opposite the bulb of the thermometer. The other capillary tubes should be held in reserve for one or more check tests which are usually necessary, the first test being merely a guide to approximate the melting-point.

Differences in melting-points of different fatty acids may indicate origin and afford information in case of possible sophistication. Thus, the melting-point of the fatty acids

from true olive oil is about two-thirds that of the fatty acids from refined cottonseed oil (22° to 26° C. versus 35° to 40° C.)*

Mixed Fatty and Resin Acids

It is preferable to liberate the fatty acids in the same beaker in which they are to be weighed. The layer of fatty acids, liberated from a hot soap solution by means of mineral acid, may form either a liquid, pasty, or solid layer on cooling.

If the layer remains liquid on cooling, then a weighed quantity of bleached beeswax (*cera alba*) or of stearic acid may be added to the hot solution, so that on chilling a "cake" is formed which may be punctured and the liquid underneath drained out. Repeat the operation, washing with boiling water two or three times until the "cake" is purified or free from salts. The washings should be passed through a ribbed filter to collect any loose particles. Then place the beaker containing the fatty acids under the funnel and dissolve any remaining fatty acids on the filter with hot 95 per cent alcohol, allowing the alcoholic washings to run into the beaker.† Dry in a water-oven and weigh. Test a portion of the weighed fatty acids for rosin (or resin acids) by the Liebermann-Storch reaction.

If present the resin acids may be separated by Twitchell's process, which depends on the fact that fatty acids in alcoholic solution, through which dry HCl gas is passed, form fatty esters, while the resin acids remain unchanged. Later, both esters and resin acids are extracted with petroleic ether, from which the resin acids are removed with dilute caustic alkali, as soluble resinates.

* See Wright, *Oils, Fats, and Waxes*, 1894, pp. 60-70; also Allen, *Comm. Org. Anal.*, 1899, Vol. II, part 1, pp. 38, 239.

† Consult Sherman's *Organic Analysis*.

*Twitchell's Method:** — Dissolve 2 or 3 grams of the fatty and resin-acid mixture in 10 times its volume of absolute alcohol, using a suitable flask. Immerse flask in water to cool solution and pass a moderate stream of dry hydrochloric acid gas through the liquid for one hour. Rapid absorption takes place. Finally, the esters separate and float and absorption ceases. The liquid, in two layers, is diluted with 5 times its volume of water and boiled until the aqueous portion is clear, the esters and resin acids floating on top. Cool, transfer to a separatory funnel with petrolic ether (B. P. below 80° C.), shake, run off acid solution, wash ether layer once with water, draw off washings, then treat ether solution in funnel with a solution of 0.5 gram caustic potash, 0.5 gram alcohol, and 50 c.c. water, whereby the resin acids are saponified. Shake and separate. The solution of resinate is drawn off and the ether layer washed once more with dilute alkaline solution. The alkaline solutions are combined and treated with hydrochloric acid to liberate resin acids which may be collected, dried, and weighed.

WAXES

True waxes, on saponification, yield a soap and higher alcoholic bodies, but no glycerol in distinction from ordinary fatty substances.

Paraffin, or mineral wax, is non-saponifiable, belongs to the "hydrocarbons," and is, therefore, not a true wax (see later).

Japan Wax (not a true wax) is a vegetable fat obtained from berries of *Rhus succedanea*, Japan, and consists chiefly of palmitin or "propenyl palmitate," $C_3H_5.(C_{16}H_{31}O_2)_3$, together with laurin and a little stearin. Its iodine absorp-

* Comm. Org. Anal., 1899, Vol. II, part 1, pp. 107-108; also Sherman's Organic Analysis.

tion is low — 4.2 per cent to 6.6 per cent, — but it requires 21 per cent to 22 per cent KHO for saponification, forming glycerol.

Myrtle or Bayberry Wax (not a true wax) is a vegetable fat obtained from the berries of *Myrica cerifera*, a tree found in Maryland, Florida, and Texas. It is a hard, pale green substance consisting mainly of palmitin, laurin, myristin, etc., and requires 21 per cent KHO for saponification with formation of glycerol. Therefore, like Japan wax, it is not a true wax.

Beeswax (yellow “*cera flava*” or white “*cera alba*”) is mostly “myricyl palmitate,” $C_{30}H_{61}.C_{16}H_{31}O_2$, with 12 to 16 per cent free cerotic acid. Its iodine absorption varies from 2 to 11 per cent, depending on quality, bleached or unbleached. It requires about 9.5 per cent KHO for saponification and no glycerol is formed.

Carnauba Wax (sulphur yellow and hard) is an exudate from leaves of wax palm, Brazil. Its composition is complex, but mostly “myricyl cerotate,” $C_{30}H_{61}.C_{27}H_{53}O_2$, with an iodine absorption of 7 to 9 per cent. It requires about 8.5 per cent KHO for saponification and no glycerol is formed.

Chinese Wax (white, crystalline, “vegetable spermaceti”) is secreted by insects on twigs of certain trees. It consists principally of “ceryl cerotate,” $C_{27}H_{55}.C_{27}H_{53}O_2$, has an iodine absorption of about 6.8 per cent, and requires about 6.8 per cent KHO for saponification, and no glycerol is formed.

Spermaceti (pearly white and crystalline) is a wax obtained from the oil in the head and blubber of the sperm whale (*Physeter macrocephalus*). It consists essentially of “cetyl palmitate,” $C_{16}H_{33}.C_{16}H_{31}O_2$, and, when pure, does not absorb iodine, although commercial samples may exhibit a slight absorption.* It requires from 12 to 13 per

* Comm. Org. Anal., 1866 Vol. II pt. I pp. 200-212

cent KHO for saponification, forming solid cetyl alcohol, white when pure.

Sperm Oil (a liquid wax), from the head and blubber of the sperm whale, consists principally of "dodecatyl oleate," $C_{12}H_{25}.C_{18}H_{33}O_2$,* or possibly "cetyl physetoleate," $C_{16}H_{33}.C_{16}H_{29}O_2$, as indicated by Wright.† It may also contain spermaceti and higher alcoholic bodies, but no glycerides. Its iodine absorption is from 83 to 85 per cent in marked contrast to spermaceti. It requires 12.5 per cent to 14.5 per cent KHO for saponification, forming potassium oleate and dodecatyl alcohol. Its specific gravity is quite low, about 0.878 and not over 0.884 at 15.5° C., and about 0.825 at 99° C.

Wool Grease, the English "Yorkshire grease," "Suint," or American "degras" — but not the true degras — is a dirty grease with foul odor, obtained by scouring wool of sheep, and contains, besides fatty acids from soap employed in scouring, cholesterol, iso-cholesterol, esters of palmitic and myristic acids, other waxy substances, nitrogenous matter, potash salts, as well as mineral oil used in lubricating the wool.‡

True Degras (French or German). English "sod-oil." This is a greasy product derived from "chamoising" skins with whale oil, fish oils, or tallow, the excess being removed by scraping or pressing and washing with lye, and the liquid treated with acid to recover the oily matter. It should not be confounded with the American "degras" or "wool grease."

Pure Wool-Fat (Adeps Lanac). The anhydrous purified

* Comm. Org. Anal., 1899, Vol. II, pt. 1, p. 45.

† Oils, Fats, Waxes, etc., 1894, p. 4.

‡ Alder Wright's Oils, Fats, Waxes, etc., 1894, pp. 272, 273, 337, 338; Thorp's Outlines, Ind. Chem., 1899, pp. 320, 415; also "Degras," U. S. Customs Decisions, J.S.C.I., 1903, p. 171, and Jour. Am. Chem. Soc., 1894, p. 535.

fat from wool of sheep.* A true wax according to Lewkowitsch.† A pale yellow neutral substance, composed mainly of cholesterol, iso-cholesterol, and fatty esters derived by extracting wool grease with solvents (as acetone or gasoline), neutralizing fatty acids with weak alkali, separating and treating with oxidizing agents until entirely free from soaps, impurities, rancidity, or unpleasant odor. M. P. 36° C.

Insoluble in, but miscible with, water which it absorbs to form an emulsified mass. Sparingly soluble in alcohol. Soluble in ether, chloroform, acetone, and benzol. Saponifiable with alcoholic potash under pressure and requires from 8.5 to 10 per cent KHO.

Lanolin (*Adeps Lanae Hydrosus*, U. S. P.). Prepared by mixing the above pure, anhydrous wool-fat with 30 per cent water, forming a yellowish-white ointment (M. P. about 40° C.), which, in turn, may be further mixed with twice its weight of water without losing its consistency as an ointment.

N. B. — The ether extraction of wool-fat, after saponification, is tedious owing to emulsification due to solubility of cholesterol in soap solutions. Authorities differ on methods of analysis.

Free Fatty Acids: — Titrate total free fatty acids in alcoholic solution. Evaporate the soapy solution, extract dry residue with ether to remove any cholesterol, etc., and acidulate for free fatty acids, insoluble in water, which may be collected and titrated separately.

Total Saponifiable and Unsaponifiable Matter: — Saponify separate portion under pressure with known excess of N/2 alkali, then "back-titrate." Deduct per cent free fatty

* Squibb's *Materia Medica*, 1906; Coblenz, *The Newer Remedies*.

† J.S.C.I., 1892, p. 135; 1896, p. 14; also *Comm. Org. Anal.*, 1899, Vol.

acids to obtain neutral wax, glycerides, etc., or precipitate insoluble calcium soaps, dry, and exhaust with acetone for cholesterol, hydrocarbons, etc.*

Paraffin or Mineral Wax (not a true wax) belongs to the "hydrocarbons," approximately $C_{27}H_{56}$, and is non-saponifiable. Obtained from petroleum, bituminous shale, wood tar, etc. Occurs native in certain localities (Galicia and Utah) in the form of fossil wax, ozocerite, etc., from which it is extracted under the name of "ceresin." Crude ozocerite varies from the translucent yellow, brown, greenish grades to the black opaque, soft or hard, forms. Pure ceresin, or refined ozocerite, pale yellowish to white, resembles bleached beeswax, melts between $61^{\circ}C.$ and $78^{\circ}C.$, and has general properties of paraffin wax.

There are several grades of paraffin with melting-points varying from $32^{\circ}C.$ to $80^{\circ}C.$ The finer and harder its structure, the higher its melting-point and greater its specific gravity — the latter varying from 0.823 (M. P. $32^{\circ}C.$) to 0.940 (M. P. $80^{\circ}C.$).

Heated with sulphur, paraffin is decomposed forming hydrogen sulphide with separation of carbon. Heated with a mixture of permanganate of potash and sulphuric acid, paraffin is violently attacked. Soluble in hot alcohol, ether, chloroform, gasoline, carbon tetrachloride, and oils, but nearly insoluble in acetone, even when warm.

Vaseline or Petrolatum (petroleum jelly). A mixture of hydrocarbons, chiefly $C_{16}H_{34}$ to $C_{20}H_{42}$, from crude petroleum residuum, purified by filtration through animal charcoal. It has a soft, greasy, jelly-like consistency and varies in color from dark brown with greenish reflex to the fluorescent yellow or opalescent white of the purer grades. Its specific gravity varies from 0.803 to 0.854, melted at

* Consult Herbig, "Analyst," 1896, p. 47; also Wright, Oils, Fats, Waxes, etc. 1804, pp. 272 and 274.

99° C., in marked contrast to paraffin at the same temperature, from 0.748 to 0.757.* Soluble in benzol, chloroform, petrolic ether, gasoline, carbon tetrachloride, and various oils at ordinary temperatures. Nearly insoluble in cold absolute alcohol. Freely soluble in boiling absolute alcohol, from which it separates on cooling. Miscible with glycerine, from which it separates and floats when heated.

Solubility of Waxy Substances

Solubility alone cannot be depended upon for the separation of waxes in admixture. To effect proper solution it is necessary that the solvent be warm or hot, but even then the waxes deposit on cooling. On experiment the writer obtained the following results:

In Boiling Absolute Alcohol

Japan wax.....completely soluble; deposits on cooling.
 Stearin.....completely soluble; deposits on cooling.
 Stearic acid.....completely soluble; deposits on cooling.
 Spermaceti.....quite soluble; deposits on cooling.
 Paraffin.....quite soluble; deposits on cooling.
 Beeswax.....partly soluble; deposits on cooling.
 Carnauba wax..almost insoluble, even in excess of alcohol.

In Acetic Anhydride

The waxes are quite insoluble in the cold solvent, but heated with solvent:

Paraffin.....melts, floats, dissolves slowly, congeals on cooling.
 Beeswax.....melts, floats, dissolves, solidifies white on cooling.
 Spermaceti...melts, floats, dissolves slowly, congeals on cooling.
 Japan wax....melts, floats, dissolves easily, congeals on cooling.
 Carnauba wax melts, floats, incompletely soluble (cloudy solution), and solidifies white on cooling.

* See *Comm. Org. Anal.* 1899, Vol. II, part 2, pp. 745, 747, 748.

Both beeswax and carnauba wax apparently become "acetylated," due possibly to presence of free myricyl alcohol or other wax alcohols.

According to Lewkowitsch, the higher fatty acids of the *acetic* family, as stearic, palmitic, lauric, cerotic, etc., form with acetic anhydride corresponding *anhydrides* which give fictitious or apparent "acetyl numbers" on neutralizing with standard alkali, even when no hydroxyl groups are present.*

In Acetone

Paraffin.....insoluble cold; slightly soluble hot.
 Beeswax.....insoluble cold; slowly soluble hot.
 Spermaceti.....insoluble cold; soluble hot.
 Japan wax.....insoluble cold; soluble hot.
 Carnauba wax...insoluble cold; very slowly soluble hot.

In Chloroform

Paraffin.....very slowly soluble cold; soluble hot.
 Beeswax.....insoluble cold; soluble hot.
 Spermaceti.....very slowly soluble cold; soluble hot.
 Japan wax.....slowly soluble cold; soluble hot.
 Carnauba wax...insoluble cold; soluble hot.

In Ether

Paraffin.....insoluble cold; soluble hot.
 Beeswax.....disintegrates cold; soluble hot.
 Spermaceti.....slightly soluble cold; soluble hot.
 Japan wax.....insoluble cold; soluble hot.
 Carnauba wax...insoluble cold; soluble hot.

In Petrolic Ether

Paraffin.....slowly soluble cold; soluble hot.
 Beeswax.....insoluble cold; insoluble hot.

* Alder Wright, *Oils, Fats, Waxes, etc.*, 1894, pp. 189, 190; also Lewkowitsch's *Oils, Fats, and Waxes*. 1900.

Spermaceti.slightly soluble cold; soluble hot.
Japan wax.insoluble cold; slowly soluble hot (cloudy).
Carnauba wax. . .insoluble cold; insoluble hot.

In Turpentine

Paraffin.hardly soluble cold; easily soluble hot.
Beeswax.hardly soluble cold; easily soluble hot.
Spermaceti.very slightly soluble cold; easily soluble hot.
Japan wax.insoluble cold; easily soluble hot.
Carnauba wax. . .insoluble cold; easily soluble hot.

In Benzol

Paraffin.insoluble cold; soluble hot.
Beeswax.insoluble cold; soluble hot.
Spermaceti.slightly soluble cold; soluble hot.
Japan wax.slowly soluble cold; soluble hot.
Carnauba wax. . .insoluble cold; soluble hot.

In Carbon Tetrachloride

Paraffin.insoluble cold; easily soluble warm.
Beeswax.disintegrates cold; easily soluble warm.
Spermaceti.hardly soluble cold; easily soluble warm.
Japan wax.hardly soluble cold; easily soluble warm.
Carnauba wax. . .hardly soluble cold; slowly soluble warm.

In Fusel Oil

Paraffin.insoluble cold; soluble hot.
Beeswax.insoluble cold; soluble hot.
Spermaceti.insoluble cold; soluble hot.
Japan wax.insoluble cold; soluble hot.
Carnauba wax. . .insoluble cold; soluble hot.

The term "cold" refers to a temperature of 8° C., the tests having been made in winter.

The term "hot" refers to the boiling-point of the respective solvent.

Note that paraffin, beeswax, spermaceti, Japan wax, and carnauba wax are all easily soluble in hot turpentine, while in hot petrolic ether, only paraffin and spermaceti are readily soluble, Japan wax imperfectly, and the others are insoluble.

Specific Gravity of Waxes in General

Japan and myrtle waxes (sp. gr. about 0.980 to 0.990 at 15° C.) are heavier than beeswax (sp. gr. about 0.960 at 15° C.), while tallow and stearine are lighter (sp. gr. 0.920 to 0.960 at 15° C.), likewise, spermaceti (sp. gr. about 0.942 at 15° C.).

Carnauba wax (sp. gr. 0.995 at 15° C.) has nearly the gravity of water. Chinese wax and stearic acid have a specific gravity of about 0.970 at 15° C., while paraffin and ceresin approximate a sp. gr. of 0.915 at 15° C.

COMPARATIVE SPECIFIC GRAVITIES OF WAX-LIKE MATERIALS

Substance.	at 99° C.	at 15° C.	Remarks.
Carnauba wax.....	0.842	0.995	Nearly as heavy as water at 15° C.
Japan wax.....	0.875	0.980-0.990	
Myrtle wax.....	0.875	0.980-0.990	Heavy as water at 11° C.
Tallow.....	0.860	0.920-0.960	
Stearine.....	0.860	0.920-0.960	
Stearic acid.....	0.830	0.970	
Beeswax.....	0.820	0.960	
Chinese wax.....	0.810	0.970	Varies with the M.P.
Spermaceti.....	0.808	0.942	
Paraffin.....	0.753	0.915	
Ceresin.....	0.753	0.915-0.926	

For gravity determinations at 15° C., Allen suggests first melting the wax, sucking up into quill, closing top with finger, chilling lower end in water to seal it, then with

the tube in a vertical position allowing the wax to cool by itself, thereby yielding a smooth stick free from cavities or air-bubbles which might produce abnormal gravities. Or, melt wax in a shallow dish over a water-bath, cool spontaneously, and cut out sample with cork-borer. Then, obtain specific gravity by immersing sample in dilute alcohol or ammonia and adjusting liquid till gravity equals that of wax immersed. With crystalline waxes, as spermaceti and Chinese wax, better results are obtained at the temperature of boiling water, using a Westphal balance.*

Melting-points of Waxy Substances

Paraffin.....	32 to 80° C., variable.
Myrtle wax.....	about 41° C.
Spermaceti.....	about 45° C.
Japan wax.....	about 56° C.
Beeswax.....	about 62° C.
Ceresin.....	61 to 70° C., variable.
Chinese wax.....	about 81° C.
Carnauba wax.....	about 85° C.

Derivatives as:

Cerotic acid.....	77.8° C.
Stearic acid.....	70 to 71° C.
Palmitic acid.....	62.2° C.
Myristic acid.....	53.8° C.
Lauric acid.....	43.5° C.
Cetyl alcohol.....	49.5° C.
Ceryl alcohol.....	70° C.
Myricyl alcohol.....	85 to 86° C.

Special substances as:

Wool fat (pure anhydrous).....	about 36° C.
"Lanolin" (hydrated wool fat)	about 40° C.

* Comp. Org. Anal., 10, 11, 12.

Cholesterol (cholesteryl alcohol)	147° C.
Iso-cholesterol (isomeric)	137 to 138° C.
Phytosterol ("plant cholesterol")	134° C.

The melting-point is useful for indicating adulteration in a particular wax, but not necessarily the extent or character, since a mixture of paraffin, beeswax, and stearic acid may have a melting-point lower than the mean of its constituents. According to Lewkowitsch,* the addition of 5 per cent carnauba wax to paraffin, ceresin, or stearic acid raises their respective melting-points materially (approximately from 10 to 15 per cent), but any further additions cause comparatively little increase in their melting-points.

VARIOUS TESTS ON WAXES

Starch or Flour. Left undissolved on treatment with hot turpentine or hot carbon tetrachloride. Wash residue with ether, and test under microscope with a solution of iodine in potassium iodide.

Mineral Matter. Examine residue.

Sulphur. Note odor on ignition. Boil 5 grams sample with dilute caustic soda, and test diluted portion by adding 1 or 2 c.c. strongly alkaline lead acetate (potassium plumbite), giving a brick-red precipitate, changing to black on boiling; or, test the cold diluted solution with sodium nitroprusside, giving a violent tint.

Rosin. Ignite and note odor, smoke, etc. Boil 5 grams sample with 20 c.c. nitric acid (sp. gr., 1.33) for one minute. Cool, dilute with equal volume of water, add excess ammonia, and shake. Pure beeswax gives a golden, yellow solution. Rosin, if present, gives a reddish-brown solution from nitro-compound.

* Oils, Fats, and Waxes, 1900, Vol. II, p. 546.

Mixed Waxes. Boiled with strong sodium carbonate solution, a cloudy liquid is first produced, which, on digestion in a water-bath, clarifies or becomes translucent as the waxes float to the top. With rosin present, a light brown resinated emulsion is produced, which clarifies on prolonged digestion, causing paraffin (if present) to separate on top of resinous mass, while stearic acid (if present) forms a soapy opaque liquid with some CO_2 froth. A high melting-point would indicate carnauba wax, beeswax, and rosin. The formation of wax alcohols is indicated under "saponification of waxes," while Japan wax, tallow, etc., yield glycerol.*

Spermaceti in Paraffin. Boil 5 grams sample cautiously with 20 c.c. concentrated ammonium hydrate in a large test-tube over a water-bath to avoid excessive frothing.

Pure paraffin melts, and floats, the liquid underneath remaining nearly clear on cooling. Spermaceti, if present, produces a cloudy-white liquid which, on cooling, solidifies to an opaque white mass. Stearic acid, if present, forms a cloudy emulsion which on cooling solidifies opaque white with frothy top. (Stearic acid, alone, dissolves to a clear viscid fluid, hot.)

Stearic Acid in Paraffin. In a hot alcoholic solution stearic acid reddens litmus, and, on adding dry sodium carbonate, liberates CO_2 with formation of soap. Paraffin alone is perfectly neutral.

Fuchsin Test: — Heat with water solution of "fuchsin f. Bac." (Grübler) or "fuchsin NX" (Heller & Merz Co.), viz., rosanilin hydrochloride. Pure paraffin remains uncolored but 5 per cent stearic acid imparts a pink color, which is enhanced by the addition of a little sodium carbonate, forming a pink emulsion. Spermaceti and Japan wax also take up the color.

N.B. — Fuchsin S. (acid magenta, or sodium salt of rosanilin) does not unite with stearic acid.*

Separation of Hydrocarbons

Paraffin, ceresin, and other hydrocarbons may be separated from the true waxes by means of the soda-lime method, which consists in:

(1) Melting about 5 grams of the sample in a suitable dish and stirring in an equal volume of powdered caustic potash.

(2) When cool, mixing one part of the pulverized mass with three times its weight of soda-lime, and heating in a test-tube or small flask at 250° C. for two hours.†

The fatty alcohol in the saponified mass is decomposed, forming hydrogen and fatty acid compound, while any hydrocarbon present remains unaffected and may be extracted with ether.

By measuring the amount of hydrogen evolved, the wax alcohol may be estimated; but this method does not separate or identify the true waxes in admixture, for ceryl, cetyl, and myricyl alcohols each produce hydrogen on fusion with soda-lime.

Beeswax itself produces a hydrocarbon (about 13.5 per cent) by this method, which must be deducted in calculations. Other waxes, by dry distillation, also give hydrocarbons.‡

Saponification of Waxes

Identification of waxes by saponification and subsequent precipitation of fatty acids with barium chloride or lead acetate in alcoholic solution is rather tedious but necessary

* See Benedikt and Knecht, *Chemistry of Coal Tar Colors*, 2d Ed., p. 161.

† Ulzer and Fraenkel, *Chem. Tech. Anal.*, 1898, pp. 123-124; *Comm. Org. Anal.*, Allen, 1899, Vol. II, pt. 1, p. 224.

‡ *Comm. Org. Anal.*, 1899, Vol. II, pt. 1, p. 225; *J. S. C. I.*, 1901, p. 87.

in certain cases. Mere treatment with alcoholic caustic potash does not always insure complete saponification, especially in presence of non-saponifiable matter, but beeswax is more readily saponified and decomposed than carnauba wax, which is almost insoluble in hot alcohol.

In the case of carnauba wax, according to the author's experience, the use of hot carbon tetrachloride as a solvent during saponification was found to be quite satisfactory, especially as it is non-inflammable and may be readily boiled out over burner after the saponification is completed. It is preferable to saponify with concentrated alkali, therefore solid caustic potash (insoluble in carbon tetrachloride) is added with a minimum quantity of water sufficient to start reaction and maintain concentration.

The resulting saponified mass may be digested with boiling alcohol and treated with a hot saturated solution of barium chloride to precipitate insoluble barium soap and separate higher alcoholic bodies (as ceryl and myricyl alcohols).

The insoluble barium soap, after filtering and washing with hot alcohol to remove any higher alcohols, is heated with dilute mineral acid to liberate fatty acids which form a "cake" on cooling and may be purified by crystallizing from alcohol.

Instead of barium-chloride precipitation, some prefer to use an alcoholic solution of lead acetate — first neutralizing excess of alkali in the hot alcoholic soap solution by using phenol-phthalein indicator and adding acetic acid until pink disappears, then precipitating the fatty acids as insoluble lead soaps. For fractional precipitation the fatty acids are liberated, dissolved in hot alcohol, and treated with small portions of alcoholic magnesium acetate, when the fatty acid of the highest molecular weight should separate first.*

* *Comm. Org. Anal.*, 1800, Vol. II, pt. 1, pp. 240-241.

Total Acid Number (Benedikt and Mangold):—Owing to the difficulty of saponifying waxes with alcoholic potash in presence of paraffin and non-saponifiable matter, the "total acid number" may be determined instead of the Koettstorfer figure.

That is, 20 grams of the wax sample are first melted, then poured into a boiling aqueous solution of caustic potash, and heated over a low flame for ten minutes.

The mass is diluted with water, then acidified with hydrochloric acid and boiled to liberate the "decomposed wax"—a mixture of fatty acids and insoluble higher alcohols, etc.

After cooling, the "cake" is boiled with two or three changes of water to remove traces of mineral acid (HCl), then transferred to a ribbed filter, placed in a hot air-bath, and melted through a filter into a clock-glass or suitable dish, after which it is chilled and broken up.

About 6 or 8 grams of the "decomposed wax" thus obtained are covered with C. P. alcohol, heated on a water-bath, a few drops of phenol-phthalein indicator added, and titrated with N/2 caustic potash to estimate the "total acid number," that is, the number of milligrams KHO required to neutralize one gram of the "decomposed wax" mixture.*

For beeswax the "total acid number" averages about 92.8, and is somewhat lower than the Koettstorfer saponification figure. For carnauba wax the number would be approximately 85.

As to the filtration of the "decomposed wax" in a hot air-bath, beeswax fatty acids require from 100° to 108° C., and remain light colored; carnauba fatty acids require at least 140° C., and tend to become dark brown.

This "decomposed wax" may also be employed to obtain

* See Ulzer and Fraenkel, Chem. Tech. Anal., 1898, p. 122; also, *Anal.*

fatty acids by precipitation with barium chloride in hot alcoholic solution.

If the "decomposed wax" derived from carnauba wax be employed to obtain myricyl alcohol through precipitation of fatty acids and recovery of the wax alcohol in the hot alcoholic filtrate, the myricyl alcohol thus obtained represents both free and combined substance, since free myricyl alcohol has been detected in carnauba wax. The free myricyl alcohol and that derived from myricyl cerotate together amount to 45 per cent of the original wax. Therefore, the weight of the myricyl alcohol obtained divided by 0.45 represents the weight of carnauba wax as such, assuming no beeswax present.* If carnauba wax were theoretically 100 per cent pure myricyl cerotate, $C_{30}H_{61}.C_{27}H_{53}O_2$, with a molecular weight of 830 as against 438 for myricyl alcohol, $C_{30}H_{61}.OH$, the yield of the latter would be 52.7 per cent instead of the average 45 per cent above stated.

If the beeswax were all myricin (myricyl palmitate), $C_{30}H_{61}.C_{16}H_{31}O_2$, with a molecular weight of 676, its equivalent in myricyl alcohol would be 64.7 per cent; but, the presence of free cerotic acid to the extent of 12 to 16 per cent, or of free myricyl alcohol in small amount, precludes any assumed calculations, since the amount of myricyl alcohol obtained from beeswax averages 53 per cent to 54 per cent, equivalent to 81.8 per cent to 83.4 per cent myricin.†

With beeswax the sum of the free cerotic acid and myricin, calculated respectively from the "free acid number" and the "ester number," is usually greater than 100, indicating the presence of some substance of lower molecular weight. Hence, in certain cases, it may be preferable to determine the myricyl alcohol as such and calculate myricin accordingly.

* Comm. Org. Anal., 1899, Vol. II, pt. 1, p. 228.

† Wright, Oils, Fats, Waxes, etc., 1891, pp. 375-376.

COMPARISONS ON WAX-LIKE SUBSTANCES AND
ROSIN

Substance.	Sp. gr. 15° C.	Melting point.	Sapon. number.	Iodine figure.	Solubility.
Paraffin (hydro- carbon)	Variable 0.915	Variable 32°-38° C	Nil	Nil	Easily soluble in hot petroleic ether, alcohol, chloroform, etc. Nearly insoluble in acetone.
Beeswax	0.960	62° C.	87-107	2-11	Insoluble in hot petroleic ether. Partly soluble in hot abso- lute alcohol. Slowly solu- ble in hot acetone. Soluble in hot chloroform, ether and benzol.
Spermaceti	0.942	45° C.	122-136	0-5	Soluble in hot alcohol and other hot solvents. Slightly soluble in cold ether.
Japan wax (vege- table tallow)	0.980	56° C.	210-238	4-7	Imperfectly soluble in hot pe- troleic ether. Soluble in hot alcohol. Slowly soluble in cold benzol; easily in hot. Soluble in hot chloroform, carbon tetra-chloride, etc.
Carnauba wax	0.995 Almost as heavy as water.	85° C.	78-85	7-13	Insoluble in hot petroleic ether. Insoluble in hot alcohol. Soluble in hot carbon tetra- chloride, benzol, and ether.
Stearic acid	0.970	70°-71°	195	Nil	Soluble in hot alcohol, ether, and benzol. Liberates CO ₂ from Na ₂ CO ₃ .
Colophony (rosin)	1.04-1.11	100°- 150° C.	175-195	140-160	Soluble in alcohol, petroleic ether, benzol, chloroform, acetone.

WAX ACIDS AND HIGHER ALCOHOLS

Cerotic Acid, $C_{27}H_{54}O_2$, M. P. 70° to 72° C.:—Exists free in beeswax (from 12 to 16 per cent), and also occurs as myricyl cerotate in carnauba wax from which it is obtained through saponification, separation of fatty acids, etc. Soluble in hot alcohol from which it deposits on cooling; also soluble in warm ether. Its lead compound is insoluble in both alcohol and ether.

Palmitic Acid, $C_{16}H_{32}O_2$, M. P. 62.2° C.:—Occurs as tri-palmitin in palm oil and Japan wax, cetyl palmitate in spermaceti, and as myricyl palmitate in beeswax, from which it is derived by saponification and precipitation of fatty acid. Soluble in hot alcohol from which it crystallizes in pearly leaflets. The barium compound is nearly insoluble in hot alcohol.

Stearic Acid, $C_{18}H_{36}O_2$, M. P. 70° C.:—Occurs as tri-stearin in lard, tallow, cacao butter, and to some extent in Japan wax, from which it is derived through saponification, precipitation, etc. Soluble in hot alcohol, from which it crystallizes in shiny leaflets. Its alcoholic solution reddens litmus and reacts with sodium carbonate, forming sodium stearate and CO_2 . Also soluble in warm ether and benzol. Slowly soluble in boiling concentrated ammonia to a clear viscid solution, solidifying white on cooling. The barium and lead compounds are insoluble in alcohol and ether. Pure stearic acid is an opaque-white solid, having a wax-like consistency and slight tallow-like taste, and is practically odorless. Much used in the candle industry, and to a limited extent in toilet preparations.

Lauric Acid, $C_{12}H_{24}O_2$, M. P. 43.5° C.:—Occurs as laurin, principally in cocoanut oil and to some extent in Japan wax and palm-nut oil from which it may be derived through saponification and distillation of fatty acid.

Easily volatile with steam; solidifies in scales. Soluble in alcohol from which it crystallizes in white needles. The lead compound is sparingly soluble in alcohol and insoluble in ether.

Myristic Acid, $C_{14}H_{28}O_2$, M. P. $53.8^\circ C.$:— Occurs as myristin in cocoanut and palm-nut oils, and to a less extent in spermaceti — derived through saponification and liberation of fatty acids. Slightly volatile with steam. Soluble in alcohol from which it crystallizes in shiny plates. Insoluble in ether (unusual). Lead compound is *soluble* in alcohol, insoluble in ether.

Myricyl Alcohol, $C_{30}H_{62}OH$, M. P. 85° to $86^\circ C.$:— Solid at ordinary temperatures. Occurs in beeswax as myricyl palmitate or myricin, from which it is set free on saponification. Soluble in hot alcohol, ether, etc.; almost insoluble in the cold; also insoluble in water. It may be obtained by saponifying beeswax in the melted state with boiling aqueous caustic potash, decomposing the soap with hydrochloric acid, dissolving the “decomposed wax” thus obtained in hot alcohol, and precipitating the fatty acids with a hot solution of barium chloride, leaving myricyl alcohol in the hot alcoholic filtrate from which it separates on cooling in white shiny masses. Purify by recrystallizing from ether. Heated with soda-lime it forms hydrogen and alkaline melissate.

Cetyl Alcohol, $C_{16}H_{33}OH$, M. P. $49.5^\circ C.$:— Solid at ordinary temperatures. Occurs in spermaceti as cetyl palmitate and is separated by saponification and precipitation of fatty acids in hot alcoholic solution with barium chloride. Soluble in warm alcohol, but more so in ether or benzol. It is insoluble in water. By evaporating the alcoholic solution it may be obtained as a “cake,” which, after purifying by ether and evaporating solvent, may be distilled almost unchanged at $340^\circ C.$, yielding a white

crystalline mass. Heated with soda-lime it forms hydrogen and alkaline palmitate.

Ceryl Alcohol, $C_{27}H_{55}OH$, M. P. $79^{\circ}C$.:—Solid at ordinary temperatures. Occurs in Chinese wax as ceryl cerotate, from which it may be separated by saponification or fusion with concentrated aqueous caustic potash, precipitation of fatty acids in hot alcoholic solution, etc., whereby the ceryl alcohol is dissolved and obtained by evaporation, and afterwards crystallized from ether. Heated with soda-lime it forms hydrogen and alkaline cerotate.

Cholesterol or Cholesteryl Alcohol, $C_{26}H_{43}OH$, M. P. $147^{\circ}C$.:—A non-saponifiable, waxy, odorless substance, frequently found in ether extract from soap solutions. Occurs in bile, yolk of egg, wool-fat, degreas, whale oil, etc. Insoluble in water. Soluble in chloroform, ether, benzol, and soap solutions. Sparingly soluble in cold, but soluble in hot, alcohol, crystallizing from latter in pearly laminæ containing 1 molecule H_2O , which it loses at $100^{\circ}C$. It crystallizes from chloroform in anhydrous needles.

Tests on Cholesterol.:—To a solution of 0.01 gram cholesterol in 2 c.c. chloroform add 2 c.c. sulphuric acid (sp. gr. 1.76).

A blood-red purple color is imparted to the chloroform layer while the sulphuric acid solution exhibits a greenish fluorescence. The chloroform layer, on evaporation or exposure, changes to blue, green, and finally yellow.*

A little cholesterol, treated with a mixture of 3 volumes concentrated hydrochloric acid and 1 volume ferric chloride solution and evaporated, gives a reddish violet color changing to blue.

If sulphuric acid is substituted for hydrochloric, a carmine to violet color is obtained.

* See Richter's *Organische Chemie*, 1891, p. 1097; also Allen's *Comm. Org. Anal.*, 1899, Vol. II, pt. 1, pp. 172, 340; and Fownes' *Elementary*

Iso-cholesterol occurs, as an isomer, with cholesterol in wool fat. Separated from each other by forming corresponding benzoates and crystallizing from ether — the “iso” compound as a light crystalline powder (M. P. 190°C.); the other in pearly laminæ (M. P. 150°C.). These benzoates, saponified with alcoholic potash, yield respectively iso-cholesterol (M. P. 138°C.) and cholesterol (M. P. 147°C.).

Phytosterol, or Phytosteryl Alcohol, $\text{C}_{26}\text{H}_{43}\text{OH}$, M. P. 132° to 138°C. :—This bears the same relation to plants that cholesterol does to animals, and is found in most vegetable or seed oils, with possible exception of olive and palm. Crystallizes in tufts or needles. Reactions similar to cholesterol.

“*Sitosterol*,” an isomer found in cereals, is a constituent of corn or maize oil, in distinction from cottonseed oil, which contains phytosterol.*

To obtain cholesterol and phytosterol, saponify 50 grams fat or oil with alcoholic soda, evaporate to syrup, dilute with boiling water, add HCl till slightly alkaline to phenolphthalein, then CaCl_2 to precipitate lime soap which is filtered, squeezed to a friable mass, and boiled with 95 per cent alcohol. Filter, add little NaOH, and evaporate dry. Extract residue with ether, filter, evaporate, and take up with hot alcohol, from which cholesterol and phytosterol separate on cooling.†

Abstract of Hehner's Method for Beeswax (Cerotic Acid and Myricin)

- (1) Dissolve 5 grams wax in 50 c.c. hot methylated spirit (redistilled from NaOH). Use small flask.
- (2) Add alcoholic phenolphthalein indicator.
- (3) Use delicate burette, and immediately titrate free acid (as cerotic)

* Gill and Tufts, Jour. Am. Chem. Soc., 1903, pp. 251-254.

† Kreis and Wolf. Analyst. 1808. D. 204.

with standard N/3 alcoholic KHO — (spirit redistilled from NaOH) — and keep liquid agitated till pink color is permanent.

- (4) 1 c.c. N/alkali (0.056 gm. KHO) = 0.410 gm. cerotic acid.
N/3 KHO = $\frac{1}{3}$ acid value. Calculate per cent KHO required.
 $0.410 \div 0.0561 = 7.31$ factor. Per cent KHO $\times 7.31$ = per cent cerotic acid.
- (5) For myricin continue process. Add further exact quantity standard alcoholic KHO (75 c.c. N/3), equivalent to 25 c.c. N/acid.
- (6) Saponify by boiling one hour, using reflux condenser, and rotate flask occasionally to break up lumps.
- (7) Detach condenser, and back-titrate with N/2 acid, using delicate burette.
- (8) The alkali used up represents myricin. 1 c.c. N/acid = 0.056 gm. KHO = 0.676 gm. myricin. $0.676 \div 0.0561 = 12.05$ factor. Average per cent KHO about 7.2 and the per cent KHO $\times 12.05$ = per cent myricin usually less than 90 per cent.

Presence of Japan Wax. — The total per cent KHO required would be above 9.5 per cent. It would be necessary to determine the amount of glycerol, and multiply this by 10 for the approximate weight of Japan wax. Extract myricyl alcohol from the saponified mass, and calculate the beeswax. Genuine beeswax gives about 54 per cent crude myricyl alcohol equivalent to 83.4 per cent myricin.*

* Wright, Oils, Fats, Waxes, etc., 1894, p. 358.

ALKALOIDAL SUBSTANCES

Ptomaines or Cadaveric Alkaloids (products of putrefaction). Examples are cadaverine, putrescine, choline, tyrotoxicon, trimethylamin, etc.

They comprise non-volatile solids as well as volatile liquids with a nauseating odor. Some are poisonous, producing convulsions, nausea, diarrhoea, etc.; others are non-poisonous. They may be tasteless or bitter, according to composition.

Their bases or salts are quite soluble in water; but melting-points are variable or uncertain.

With mixed solutions of ferric chloride and potassium ferricyanide:*

Cadaverine or its salts. Blue color.

Choline and putrescine. Nothing.

All ptomaines are precipitated by the phospho-molybdic acid reagent, and, in general, respond to most of the tests for vegetable alkaloids, hence the uncertainty in toxicological work.

Vegetable Alkaloids (nitrogenous plant substances). Examples are aconite, atropine, morphine, strychnine, cocaine, codeine, quinine, caffeine, etc., of which aconite is, perhaps, the most poisonous and caffeine the least. They are usually regarded as derivatives of pyridin or quinolin, and, in the case of caffeine, uric acid.

In toxicological work, their separation and identification is somewhat intricate, since they must not be confounded with various glucosides and bitter principles of a poisonous nature, or with ptomaines.

Only a few general schemes are offered.

* For details see "Toxicology," p. 5.

SOME VEGETABLE ALKALOIDS (Derivatives of Pyridin)

Source.	Alkaloid.	Formula.	Remarks.
Cinchona bark	Quinine	$C_{20}H_{24}N_2O_2$	Antipyretic, tonic.
	Quinidine	$C_{20}H_{24}N_2O_2$	Antipyretic, quinine substitute.
	Cinchonidine	$C_{20}H_{24}N_2O$	Tonic (intermittent fever).
	Cinchonine	$C_{20}H_{24}N_2O$	Tonic (malaria, intermittent fever).
Opium plant (Papaver somniferum)	Morphine	$C_{17}H_{19}NO_3 \cdot H_2O$	Hypnotic, narcotic, analgesic.
	Codeine	$C_{18}H_{21}NO_3 \cdot H_2O$	Milder analgesic.
Artificial from morphine	Narcotine (not nicotine)	$C_{22}H_{23}NO_7$	Hypnotic, antipyretic.
	Apomorphine (hydrochloride generally used)	$C_{17}H_{17}NO_2 \cdot HCl$	Emetic, hypnotic, heart depressant.
Sedative and hypnotic alkaloids. Natural tropines from Atropa Belladonna (leaf and root), Hyoscyamus niger (leaf and seed), and Datura Stramonium (leaf and seed).	Atropine	$C_{17}H_{23}NO_3$	Heart and respiratory stimulant.
	Hyoscyamine	$C_{17}H_{23}NO_3$	Hypnotic, sedative (insanity, tuberclosis).
Artificial tropine (oxycodone)	Hyoscyne	$C_{17}H_{23}NO_4$	Hypnotic, sedative (mania, alcoholic tremor).
	Homatropine (hydrobromide generally used)	$C_{16}H_{21}NO_3 \cdot HBr$	Dilates pupil of eye strongly. Ophthalmic surgery, antispasmodic, sedative, anodyne.

SOME VEGETABLE ALKALOIDS (Derivatives of Pyridin) — (Continued)

Source.	Alkaloid.	Formula.	Remarks.
rychnine alkaloids from Strychnos nux vomica	Strychnine Brucine	$C_{22}H_{24}N_2O_2$ $C_{23}H_{26}N_2O_4$	Heart, respiratory, and nerve stimulant, tonic. Heart and nerve stimulant, but much milder than strychnine.
aconite root (Aconitum napellus)	Aconitine (representative)	$C_{34}H_{47}NO_{11}$	Very poisonous. Organoleptic or "lighting-ling" effects. Anodyne, antipyretic (rheumatism, neuralgia, and gout).
coca leaves (Erythroxylon coca)	Cocaine (hydrochloride generally used)	$C_{17}H_{21}NO_4$	Local anesthetic (benumbs), mydriatic, and anodyne.
hydrastine alkaloids (from plant, Hydrastis canadensis)	Berberine (yellow). Hydrastine (colorless or white)	$C_{20}H_{17}NO_4$ $C_{21}H_{21}NO_6$	Antiperiodic, intestinal catarrh, splenic enlargement, etc. Hemostatic, astringent, tonic.
tobacco plant	Nicotine	$C_{10}H_{14}N_2$	Narcotic, poisonous, antidote to strychnine. Hypodermically, in bladder paralysis.

Dosage for Alkaloids

Quinine sulphate..... $\frac{1}{2}$ -5-15 grains.
 Quinidine sulphate..... $\frac{1}{2}$ -5-10 grains.
 Cinchonidine sulphate.....1-15-30 grains.
 Cinchonine sulphate.....1-15-30 grains.

Morphine sulphate..... $1\frac{1}{2}$ - $\frac{1}{2}$ -2 grains (maximum per day).
 Codeine sulphate..... $\frac{1}{2}$ - $1\frac{1}{2}$ -5 grains (maximum per day).
 Apomorphine hydrochloride.. $\frac{1}{80}$ - $\frac{1}{20}$ -1 grain (maximum per day).
 Narcotine hydrochloride..... $1\frac{1}{2}$ -3-15 grains (maximum per day).

Atropine sulphate.. $1\frac{1}{20}$ - $\frac{1}{10}$ - $\frac{1}{5}$ grain (maximum per day). Very poisonous.
 Homatropine hydrobromide.. $1\frac{1}{20}$ - $\frac{1}{10}$ - $\frac{1}{5}$ grain. Less toxic than atropine.
 Hyoscyamine (amorphous) .. $1\frac{1}{20}$ - $\frac{1}{10}$ - $\frac{1}{8}$ grain.
 Hyoscine hydrobromide..... $\frac{1}{40}$ - $\frac{1}{20}$ - $\frac{1}{10}$ grain.

Strychnine sulphate..... $\frac{1}{60}$ - $\frac{1}{15}$ - $\frac{1}{3}$ grain (maximum per day).
 Brucine sulphate..... $1\frac{1}{2}$ - $\frac{1}{2}$ - $\frac{3}{4}$ grain (maximum per day).

Aconite sulphate.. $\frac{1}{80}$ - $\frac{1}{20}$ - $\frac{1}{10}$ grain (maximum per day). Very poisonous.

Cocaine hydrochloride..... $\frac{1}{2}$ -1-6 grains (maximum per day).
 Hydrastine hydrochloride... $\frac{1}{2}$ -1-1 $\frac{1}{2}$ grains (maximum per day).

GENERAL SOLUBILITY OF ALKALOIDAL SUBSTANCES

Free Bases. With few exceptions they are almost insoluble in pure water.

Alkaloidal Salts. Quite soluble in acidulated water, as sulphates, acetates, and chlorides.

In Alcohol both bases and salts are quite freely soluble.

In Ether, Chloroform, Petrolie Ether, and Benzol the salts are generally insoluble. The bases exhibit different solubilities, and are more readily extracted with warm solvents. Morphine and strychnine are practically insoluble

in ether or petrolic ether. Strychnine is quite soluble in chloroform and somewhat in benzol. Not so morphine, which is best dissolved in warm amyl alcohol especially from ammoniacal solutions.

Use of Immiscible Solvents

(1) Acidify aqueous solution with sulphuric acid and treat with petrolic ether to remove hydrocarbons, fats, oils, resins, etc.

(2) Separate acid aqueous portion and treat with chloroform to remove glucosides, weak alkaloids, etc.

(3) Again separate aqueous portion, add mixture of ether-chloroform (1 : 1) — which sinks — and then make alkaline with ammonia to liberate alkaloidal bases which are taken up by immiscible solvent.

(4) Remove solvent, and wash same with acidulated water to form alkaloidal salts, which are thereby transferred to the aqueous portion. Separate as before.

(5) This acid aqueous solution is rendered alkaline with ammonia, and treated successively with petrolic ether, benzol, and finally amyl alcohol to obtain group separations.

From acid solutions, the following feebly basic alkaloids — caffeine, colchicine, narcotine, and theobromine — are extracted by chloroform, their salts being more or less decomposed by water. Nearly all other alkaloids resist extraction from acid solutions by immiscible solvents, thereby affording separation from glucosides and various other bitter principles.*

* Prescott, *Outlines of Prox. Org. Anal.*, 1893, pp. 136 and 137; Kippenberger, *Analyst*, 1895, p. 201.

A TABLE OF SOLUBILITIES OF CERTAIN ALKALOIDS
IN WATER AND BY EXTRACTION FROM ALKALINE
AQUEOUS SOLUTIONS — (Not acid)

Substance (Base).	Cold water.	Boiling water.	Ethyl ether.	Chloro- form.	Benzol.	Petrolie ether.
Aconitine	Sl. sol.	Sol.	Sol.	Fr. sol.	Sol.	Insol.
Atropine	Sl. sol.	Sol.	Sol.	Fr. sol.	Sol.	Insol.
Hyoscyamine	Sl. sol.	Sol.	Fr. sol.	Fr. sol.	.....	.....
Hyoscyne	Sl. sol.	Sol.	Sol.	Sol.	Sol.	Insol.
Strychnine	Insol.	N. insol.	N. insol.	Sol.	Sol.	N. insol.
Brucine	Insol.	Sl. sol.	N. insol.	Sol.	Sol.	Sl. sol.
Morphine	Insol.	Sl. sol.	N. insol.	N. insol.	Insol.	Insol.
Codeine	Sol.	Sol.	Sol.	Sol.	Sol.	Insol.
Apomorphine	Sl. sol.	Sol.	Sol.	Sol.	Sol.	.....
Narcotine	Insol.	Insol.	Sol.	Fr. sol.	Sol.	N. insol.
Hydrastine	Insol.	Insol.	Sl. sol.	Fr. sol.	Sol.	Insol.
Berberine	Sl. sol.	Fr. sol.	Insol.	Sl. sol.	Sl. sol.	Insol.
Cocaine	Sl. sol.	Sol.	Sol.	Sol.	Sol.	Sol.
Quinine	N. insol.	N. insol.	Sol.	Sol.	Sl. sol.	Sl. sol.
Cinchona	Insol.	N. insol.	Sol.	Sol.	.....	N. insol.
Cinchonine	Insol.	N. insol.	Sl. sol.	Fr. sol.	.....	.....
Caffeine	Sol.	Sol.	Sl. sol.	Sol.	Sl. sol.	Insol.
Theobromine	N. insol.	Sl. sol.	N. insol.	Sp. sol.	Sl. sol.	Insol.
Physostigmine	N. insol.	Sl. sol.	Sol.	Sol.	Sol.	Insol.
Gelsemine	N. insol.	Sl. sol.	Sol.	Sol.	.....	.....
Emetine (ipecac)	N. insol.	Sl. sol.	Sol.	Sol.	Sol.	Sl. sol.
Colchicine	Sol.	Sol.	Sp. sol.	Sol.	Sol.	Insol.
Nicotine (tobacco)	Sol.	Volat.	Sol.	Sl. sol.	Sol.	Sol.
Conine (hemlock)	Sol.	Volat.	Sol.	Sol.	Sol.	Sol.

ALKALOIDAL REACTIONS WITH ACIDS

On porcelain.	With conc. H_2SO_4 , few drops.	With conc. HNO_3 , few drops.	Subs. mixed with cane sugar. Place upon drop of conc. H_2SO_4 .	Subs. with conc. H_2SO_4 ; add frag- ment of $\text{K}_2\text{Cr}_2\text{O}_7$.
Aconite	Yel. to br.	Red brown	Red	Greenish
Atropine	Colorless	Colorless	Colorless	Bit. almond odor
Berberine	Or. to green (warming)	Red brown	.....	.....
Brucine	Blood red	Red	Colorless	Orange
Caffeine	Colorless	Colorless	Colorless	Slowly green
Cocaine	Colorless	Colorless	.....	Pale pink
Codeine	Colorless	Yel. to red	Red	Greenish
Colchicine	Yellow	Violet blue	.....	.....
Gelsemine	Colorless to red on warming	Greenish (impure)	Red	.....
Morphine	Red to yellow	Purple on warming	Purple to blue, black	Greenish
Nicotine	Colorless	.....	Colorless	Greenish
Physostigmine	Yellow	Yellow to red on warming	.....	Purple to greenish
Quinine	Colorless	Colorless	Colorless	.....
Strychnine	Colorless	Colorless	Colorless	Blue, violet, orange (changing)
Veratrine	Reddish to cherry-red (heating)	Yellow	Green to blue	Greenish

Alkaloidal Reagents

Froehde's Reagent:—Ten milligrams sodium molybdate in 10 c.c. concentrated sulphuric acid gives various colorations with many alkaloids and some glucosides.

Phospho-molybdate Reagent:—Yellow ammonium phospho-molybdate (previously well washed) is heated in suspension in water, adding sodium carbonate until clear. The solution is evaporated and the residue ignited until ammonia is driven out. If reduction or blackening occurs, moisten with nitric acid and reheat. The residue is dissolved in warm water strongly acidified with nitric acid,* making 1 part residue in 10 parts solution.

This reagent precipitates most of the alkaloids from acidulated solutions yielding yellowish or brownish precipitates which, on treatment with ammonia, produce bluish or colorless effects thereby affording a means of distinction.

With Froehde's reagent.	Phospho-molybdate reagent.	
	Precipitate.	Plus ammonia.
Aconite, yellowish brown color	Yellow ppt.	Blue solution
Atropine, colorless.	Yellow ppt.	Blue to colorless solution
Berberine, greenish to brown. . .	Yellow ppt.	Blue solution
Brucine, red to yellow.	Orange ppt.	Green-yellow sol.
Caffeine, colorless.	Yellow ppt.	Colorless solution
Codeine, green, blue, yellow. . .	Brown-yellow	Green solution
Colchicine, yellow.	Yellow ppt.	Bluish, later green
Cocaine.	Yellow white	Colorless
Gelsemin, dark brown (?)	Yellow white	Blue
Morphine, violet to blue.	Yellow	Dark blue solution
Nicotine, no color or yellow. . .	Yellow	Blue solution
Physostigmine.	Yellow	Blue precipitate.
Quinine, colorless to green.	Yellow white	White precipitate
Strychnine, colorless.	Yellow white	Colorless
Veratrine, slowly, cherry-red. . .	.....	.....

* Wells, Fres. Qual. Anal., 1897, p. 664; also Prescott's Prox. Org. Anal.,

The tests are preferably made on a white porcelain tile, or on glass with a white background.

In the cane-sugar acid test, any browning of the sugar should be discounted and only bright colors noted.

The above tests are not by any means conclusive, since many glucosides and other bitter principles give similar color effects with concentrated acids.

BITTER PRINCIPLES

(Glucosides and Non-glucosides)

Glucosides. Substances, which on fermentation or by hydrolysis, yield an active principle and glucose. Generally soluble in water and alcohol, but not in ether. Extracted from acid solutions by chloroform-ether and thus separated from stronger alkaloids.* Among the important glucosides are:

Digitalin, $C_{29}H_{46}O_{14}$ (from leaves and roots of *Digitalis purpurea*), heart tonic, poisonous.

Salicin, $C_{13}H_{18}O_7$ (from willow-bark), antirheumatic, tonic (malaria), without unpleasant effects of salicylic acid.

Saponin, $C_{17}H_{26}O_{10}$ (root, *Saponaria officinalis*; bark, *Quillaja saponaria*), expectorant, emetic, emulsifier. Taken hypodermically it is poisonous. Dry powder causes sneezing. Foam producer (beverages). Detergent (textiles).

Quillajic Acid, $C_{19}H_{30}O_{10}$ (from soap bark, *Quillaja saponaria*). The sodium salt causes violent irritation of throat, nose, and eyes (caustic action, coughing, sneezing, tears, and swelling of eyelids). Hypodermically, fatal poison. Soap bark itself (infusion or powder) is used in bronchitis and eczema; foam producer (shampoos and beverages); emulsifier and detergent (textiles). Dust from bark is irritating.

* Comm. Org. Anal., 1896, Vol. III, pt. 3, p. 92.

Sarsaparillin, $C_{20}H_{32}O_{10}$ (from root of *Smilax officinalis*). The extract is used as a tonic, and for skin diseases.

Absinthin, $C_{16}H_{20}O_4$ (glucoside from wormwood, *Artemisia absinthium*). Boiled with dilute sulphuric acid yields dextrose. It is a yellowish, very bitter substance. Soluble in water, alcohol, and ether. Associated with an essential oil having toxic effect in absinthe drinking.

Strophanthin, $C_{16}H_{26}O_8$ (?) (*Strophanthus kombé*), is a powerful poison, producing muscular contraction and rigidity. Heart tonic (in place of digitalin). Dose, $\frac{1}{800} - \frac{1}{60}$ grain.

Jalapin, $C_{34}H_{56}O_{16}$ (resinoid, from root *Ipomœa orizabensis*).

Scammonin, a resinoid identical with jalapin, but from *Convolvulus scammonia*.

Convolvulin, $C_{31}H_{50}O_{16}$ (resinoid, from root *Ipomœa purga*, true jalap). All three resinoids are strongly purgative.

Non-glucosides. Neutral bitter substances, more or less soluble in water, employed in medicine and beverages. From acid solutions they are generally removed by ether or chloroform.*

The aloins (from various species of aloe). Composition uncertain. $C_{16}H_{18}O_7$, (?). Yellowish, resin-like masses. Soluble in water, alcohol, and amyl alcohol (hot). Nearly insoluble in ether; insoluble in chloroform and benzol. Tonic, laxative (jaundice, constipation).

Santonin, $C_{15}H_{18}O_3$ (from buds, species *Artemisia*). Pale yellowish or pearly crystals. Poisonous and slightly bitter. Sparingly soluble in water, easily in alcohol, ether, and chloroform. Tonic (epilepsy, worms).

Picrotoxin, $C_{30}H_{34}O_{13}$ (from *Cocculus indicus*, berries). Feathery crystals or prisms. Poisonous (especially to fish) and intensely bitter. From 2 to 3 grains cause symptoms

* *Comm. Org. Anal.* 1866, Vol. III, pt. 2, p. 186

analogous to strychnine. Sparingly soluble in water. Easily soluble in alcohol, benzol, amyl alcohol, ammonia, and acidulated water (from latter by ether and chloroform). Nerve tonic (paralysis, epilepsy).

Colocynthin, $C_{56}H_{84}O_{23}$ (?), (from *Citrullus colocynthis*, bitter fruit). Yellowish powder. Poisonous and intensely bitter. Easily soluble in water and hot alcohol, also in acetic ether. Insoluble in ether and petrolic ether. Purgative.

Gentiopiecin, $C_{20}H_{30}O_{12}$ (from gentian root, *Gentiana lutea*). Bitter principle, as distinguished from the yellowish, tasteless coloring matter, gentisin. Soluble in water, alcohol, and ether; somewhat in chloroform. Tonic, gout, dyspepsia, hysteria.

Hop Bitters, made from "lupulin" (yellow dust from female flowers of *Humulus lupulus*), containing a bitter principle (lupulic acid, $C_{50}H_{70}O_8$), hop-resins, and a hop-oil. Soluble in boiling water; in alcohol, ether, and chloroform. Tonic, and also used in brewing beer.

Quassin, $C_{32}H_{42}O_{10}$ (from quassia wood). Intensely bitter crystals. Soluble in hot water, in alcohol, ether, and chloroform. Bitter tonic, and substitute for hop bitters.

Chiratin, $C_{26}H_{48}O_{15}$ (from East Indian chiretta). Soluble in hot water, in alcohol, and ether (easily from acid solutions). Bitter tonic.

TESTS ON A FEW BITTER PRINCIPLES

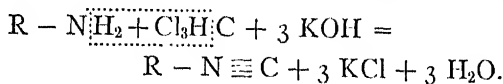
	With conc. H_2SO_4 .	With Froehde's Reagent.	Remarks.
Salicin	Bright red.	Violet color.	With H_2SO_4 and fragment $\text{K}_2\text{Cr}_2\text{O}_7$ — odor of salicyl aldehyde.
Digitalin	Golden yellow to red.	Orange red to brown.	
Strophanthin	Dry, greenish to brown. Solution cloudy.	No change.	With HNO_3 , rose color.
Jalapin	Purple, then brown, black.		
Picrotoxin	Yellow to orange-red on warm'g. (Brownish fluorescence.)	Solutions unaffected.	With conc. HNO_3 , it dissolves. With conc. H_2SO_4 and fragment $\text{K}_2\text{Cr}_2\text{O}_7$ — red brown (Prescott).
Colocynthin	Orange-red.	Cherry-red (slowly).	Moistened with phenol and drop conc. H_2SO_4 , blood-red to orange.
Quassin	Negative or yellow.	Greenish brown.	Not precipitated by neutral lead acetate. Gives Br. ammonia test.
Chiratin	Brown.	Brown.	Not precipitated by neutral lead acetate. No Br. ammonia test.

N.B. — Neutral lead acetate precipitates true hop bitter in distinction from quassin and chiratin. (See Allen's *Comm. Org. Anal.*, 1896, Vol. III, pt. 3, pp. 185-191.

MISCELLANEOUS SUBSTANCES

SCHEME FOR THE IDENTIFICATION OF ACETANILID, PHENACETIN, QUININE SULPHATE, ETC.*

The test made by boiling the substance with caustic potash and chloroform is one of the most important in the scheme given below. It is known as the "carbylamin reaction" or "isonitril test," and is common to those compounds which are classed as *primary amines* ($\text{R}-\text{NH}_2$).



* F. S. HYDE, *Tour. Amer. Chem. Soc.*, 1895, p. 933; also *Analyst*,

SCHEME FOR THE IDENTIFICATION OF ACETANILID, PHENACETIN, QUININE SULPHATE, ETC.

Pure substance.	Melting-point, ° C.	Solubility in water.	Solution of substance in water.			
			Boiled with excess caustic potash and few drops chloroform.	Ferric chloride.	Dilute nitric acid.	Bromine water.
Acetanilid (Phenyl acetamide) $C_6H_5NH.COCH_3$	113°	Soluble in cold; more so in hot.	Odor of isonitril.	Yellow solution. Red on boiling.	Colorless.	White crystals. Para-brom-acetanilide.
Exalgin (Methyl phenyl acetamide) $C_6H_5N.CH_3.COCH_3$	101°	Not very soluble, cold; easily soluble, hot.	No odor of isonitril. Class of secondary amines.	Yellow solution. Cloudy red on boiling.	Colorless.	No precipitate.
Phenacetin (Acetylparacetamidophenetol) $C_6H_4.O_2C_2H_5.NH.COCH_3$	135°	Soluble with difficulty.	Odor of isonitril.	Yellow solution. Blood-red on boiling.	Cloudy yellow solution. Crystals of nitro compound.	No precipitate.
Phenecoll hydrochloride (Glycocollparacetamidophenetol) $C_6H_4.O_2C_2H_5.NH_2.HCl$	No. M. P. HCl comp.	Very soluble.	Odor of isonitril.	Yellow solution. Darkens and gives orange precipitate on boiling.	Colorless.	No precipitate.
Salol (Phenol salicylate) $C_6H_4.OH.COOC_6H_5$	43°	Soluble with difficulty.	No odor of isonitril. Yellow solution.	Yellow solution. Blood-red on boiling.	Colorless.	No precipitate cold; white cloudy compound on boiling.
Resorcin (Metadioxybenzene) $C_6H_4(OH)_2$	118°	Easily soluble.	No odor of isonitril. Carmine-red solution.	Dark violet. Yellowish on adding drop of sulphuric acid.	Yellow solution.	Yellowish precipitate dissolving immediately.
Quinine sulphate $C_{20}H_{24}N_2O_2.H_2SO_4$	....	Slightly soluble. With few drops of sulphuric acid dissolves with blue fluorescence.	Base precipitates and dissolves on heating.	Yellow solution.	Colorless with bluish fluorescence.	Dry substance on porcelain with weak bromine water gives green coloration on adding two or three drops ammonia water = Fehlelo-quin test.
Antipyrin (Phenyl dimethylpyrazolon) $HOC_6H_3(CH_3)_2C_6H_5$	113°	Soluble.	Nothing.	Blood-red. Disappears on adding a drop of sulphuric acid.	Colorless.	Yellowish-white precipitate.

Phenacetin:—Contrary to some writers, phenacetin *will* give the isonitril test, and hence cannot be distinguished from acetanilid by this reaction.*

Exalgin does not respond to this test because it is a *secondary* amine; hence a distinction from acetanilid, phenacetin, and phenocoll.

The odor of raspberries attributed to exalgin, when heated, is somewhat misleading. It is certainly aromatic, but may resemble either strawberries or mulberries.

By boiling acetanilid with an alkaline solution of sodium hypobromite (NaBrO) or with alkaline permanganate, the same odor of isonitril is produced, but the reaction is complicated and not perfectly understood. However, it is assumed that the benzene ring constituting the nucleus of the compound is partially broken down by the strong oxidizing action of the hypobromite or permanganate, and thus furnishes the necessary carbon substitution in the formation of isonitril.

In making the carbylamin, isonitril, or "isocyanide" test, as it may be called, it is preferable to have the solution strongly alkaline in every case to insure a more complete decomposition as well as quicker reaction and a more perceptible odor.

SPECIAL TESTS FOR ACETANILID, PHENACETIN, AND SALOL

The substance should be pulverized before making a test. Compressed tablets often resist solution and thus hinder reaction. Both phenacetin and acetanilid give the "isonitril test," and therefore cannot be distinguished from each other by this reaction. Salol does not give the "isonitril" odor.

Solubility in water serves as a better distinction than the respective solubilities in alcohol, ether, chloroform, or benzol.

* *J. Anal. and Appl. Chem.* 1892, 7, 251.

Acetanilid may be roughly separated from phenacetin by treating with hot water and filtering quickly. From the filtrate, on cooling, the acetanilid crystallizes out with traces of phenacetin.

Phenol-glycerol Test: — On boiling with an aqueous phenol-glycerol solution, then cooling, and adding an excess of filtered bleaching-powder solution:

Acetanilid gives a brownish color, changing to an indigo-blue.

Phenacetin gives a flocculent, light, coffee-colored precipitate.

Bromine Test for Acetanilid: — Shake powdered acetanilid vigorously with three or four times its quantity of water in a test-tube at the ordinary temperature and filter the solution. To the filtrate add strong bromine water, which is first decolorized and finally, with excess of reagent, gives a white precipitate of the para-brom-acetanilid. Phenacetin gives neither coloration nor precipitate.

Salol has the lowest melting-point (43°C.); acetanilid (113°C.), and phenacetin (135°C.). A good characteristic test for salol consists in boiling with caustic potash solution, whereby potassium salicylate and phenate are formed and remain dissolved in the solution, which is perfectly clear. On cooling and saturating the solution with hydrochloric acid, the salicylic acid separates in clusters of beautiful fine white needles, while the solution gives off the odor of phenol. The salicylic acid may be separated by filtration, and the filtrate shaken with ether to extract phenol.

MODIFICATION OF THE THALLEIOQUIN TEST FOR QUININE*

It is extremely important for the success of this test that the reagents employed should be dilute. Some authorities

* *E. S. Hume, Jour. Amer. Chem. Soc., Vol. XIX, 1897, p. 221.*

give the quantity of each reagent necessary, without stating the proper dilution, thereby causing much inconvenience.

The light-green coloration produced on porcelain by contact of the quinine salt with weak bromine or chlorine water and ammonia is not nearly so striking as the brilliant emerald-green color obtained by using dilute solutions in a test-tube.

Usually, the analyst deals with unknown quantities, or mere traces, but, for experiment, it will be found convenient to use from three to five milligrams of the quinine salt for each test. (With larger amounts there is a tendency to form bulky precipitates.)

For example, place three to five milligrams (0.003-0.005 gram) quinine sulphate in a test-tube and add about five c.c. distilled water. Acidulate with *one* drop (not more) of dilute sulphuric acid (1 : 4) which immediately dissolves the quinine sulphate with a blue fluorescence. An excess of the acid should be avoided.

At this point various authorities recommend the addition of weak bromine or chlorine water; but the writer has found that if a clear, filtered solution of calcium hypochlorite (bleaching powder) be substituted for the bromine or chlorine water, the results will be more satisfactory so far as certainty and brilliancy of the test are concerned.

The points to be observed are as follows: After acidulation with one drop of sulphuric acid (1 : 4), the hypochlorite solution is added through a small filter to the quinine solution in the test-tube, until the blue fluorescence just disappears, and the solution acquires a faint golden tint; then add a few drops of dilute ammonia (1 : 3) when a clear emerald-green color should appear. (Thalleioquin test.)

The tint, thus produced, seems to be more brilliant than that obtained through the agency of bromine water.

to this green solution, a blood-red tint will be produced which may be considered confirmatory. This is not always the case, however, when bromine water has been used in the preliminary operation.

Potassium or sodium hypobromite is not applicable on account of the strong alkali which tends to precipitate the white quinine base and thus interfere with the brilliancy of the test. Chlorinated soda (Labarraque's solution) likewise gives uncertain results, the tints varying from yellowish green to violet.

PREPARATION OF SODIUM NITROPRUSSIDE*

The literature referring to this compound is usually more or less incomplete in regard to the details of its preparation; but, unless it is prepared in the pure state, its use as a delicate reagent is somewhat impaired.

- Place sixty grams pulverized potassium ferrocyanide in a medium-sized evaporating dish, and pour on it a solution consisting of 150 grams concentrated nitric acid (sp. gr. 1.42) diluted with 100 c.c. of water. Perform the operation under a hood or in a draft of air. When the evolution of gases has ceased, evaporate on a water-bath with occasional stirring until a few drops of the liquid, mixed with water in a test-tube, no longer give a blue color with ferrous sulphate solution but, instead, a dark greenish cloud.

It may be necessary to continue the evaporation for an hour or more before the final test is obtained. However, the liquid which has a dark reddish brown color, should be evaporated to about one-half of its original bulk to insure success. Allow to cool slowly over night, when crystals of potassium nitrate, blackened with impurities, separate out in stellated masses or needles.

Decant the liquid from the crystals (which are rejected)

* E. S. HYDE, Jour. Amer. Chem. Soc., Vol. XIX, 1897, p. 22.

and neutralize it by stirring in dry sodium carbonate, producing a greenish-brown froth and a red solution. This will require some patience on account of frothing; heat on the water-bath, filter, and wash. Evaporate the red filtrate to one-half of its bulk or more, and allow it to crystallize by slow cooling on the water-bath.

The crystallization consists mostly of crusts of sodium and potassium nitrates, together with little red needles of nitro-prusside. Pour off the mother liquor and treat the impure crystals with as little water as possible, just enough to dissolve the nitrates and leave the red crystals. Then with this nitrate solution in the same dish, wash or "pan out" (with a rotary motion) the impurities from the crystals.

These red crystals may be recrystallized by dissolving in a small quantity of distilled water and evaporating the deep-red solution in a beaker to small bulk, or better still until there is an incipient formation of crystals.

By slow cooling, as before, clusters of beautiful red rhombic needles are produced. Pour off the mother liquor and dry the crystals on filter paper.

The yield averages about twenty-five per cent by weight of the ferrocyanide used. In one experiment the writer obtained seventeen grams of the nitroprusside from sixty grams ferrocyanide, or over 28 per cent yield. Very little is gained by treating the mother liquors for an extra yield, especially in the case of small amounts.

Sodium nitroprusside ($\text{Na}_2\text{Fe}(\text{NO})\text{Cy}_6 + 2 \text{H}_2\text{O}$) has no melting-point. When heated in a glass tube, the crystal gives off moisture and becomes black without disintegration. It is slowly soluble in cold water, but easily soluble in hot water. It is best known as a very delicate reagent for sulphur in the form of alkaline sulphides, producing violet colored solutions which gradually lose color on

Certain organic compounds also react with sodium nitroprusside. For instance, with a weak aqueous solution of nitroprusside made slightly alkaline with caustic soda, formaldehyde gradually produces a dark amber tint; acetic aldehyde gives a blood-red color, becoming darker on standing, and finally violet after two or three hours; acetone produces a blood-red solution fading gradually to orange red; and benzaldehyde gives no coloration.

A GENERAL SCHEME FOR SEPARATING ORGANIC SUBSTANCES*

The substance is treated with water acidulated with sulphuric acid and the mixture agitated with ether in a separatory funnel.

Acid Aqueous Solution Treated with Ether

I. <i>Ether layer.</i>	Treat ether layer separately with an equal volume of dilute caustic soda (NaOH).	
	<i>Immiscible solvent.</i>	<i>Alkaline solution.</i>
Hydrocarbons, fatty and essential oils, higher fatty and aromatic acids, higher alcohols, phenols, camphors, glucosides, resins, coloring matters, hop bitters, artificial drugs, weak alkaloids. <i>N. B.</i> — Presence of methyl or ethyl alcohols and also acetic acid would interfere with immiscible solvent. Remove beforehand.	Paraffin, mineral, and rosin oils, naphthalene, anthracene, turpentine and essential oils, camphor and menthol, nitro-benzol, nitroglycerine, amyl alcohol, wax alcohols, cholesterol, chlorophyll, caffeine, digitalin, theobromine, piperine, colchicine, acetanilid, phenacetine and possibly fixed oils and fats not saponified in cold.	Soaps as stearates, oleates, and palmitates; rosin as resinate; phenolic bodies as phenates, benzoates, and salicylates; cresol as cresotate, thymol and "cresote" compounds; acid dyes as picrates, alizarin, safranin, etc.; glucosides as picrotoxin and cantharides. <i>N. B.</i> — Dyes or colors remain mostly in original acid solution — very little extracted.
II. <i>Acid solution.</i>	Add 1/2 vol. ether-chloroform (1 : 1) and make alkaline with ammonia.	
	<i>Immiscible solvent.</i>	<i>Alkaline solution.</i>
Carbohydrates, soluble organic acids, alkaloidal salts, coloring matters, pyridin and anilin, proteids.	Strychnine, quinine, atropine, acetonine, cocaine, codeine, hyoseyamine, cocaine, brucine, anilin, etc. <i>N. B.</i> — Morphine is sparingly soluble in ether-chloroform.	Sugars, dextrin, gums, acetates, citrates, tartrates, oxalates, and lactates; albumen, casein, gelatine, cochineal, cudbear, logwood, morphine, and cinchonine.

SCHEME:—HAIR TONICS, COLOGNE WATER, MEDICINAL PREPARATIONS, ETC.

Distil off alcohol and determine as in wine analysis.

Acidify solution with sulphuric acid, and extract with petrolic ether, using a stop-cock separator.

Acid Aqueous Solution Extracted with Petrolic Ether

<i>Extract A</i> Contains the hydrocarbons, fixed oils, essential or volatile oils. Distil with steam to separate volatile from any fixed oils.	<i>Aqueous solution A</i> Place in separator and treat with sulphuric ether.			
	<i>Extract B</i> Resinous bodies, balsams and possibly hop bitters, quassin, picrotoxin, gentian, chiretta.	<i>Aqueous solution B (still acid)</i> Treat with chloroform.		
		<i>Extract C</i> Caffeine, cantharidin, theobromine, possibly resins.	<i>Solution C</i> Make alkaline with ammonia and again treat with chloroform.	
			<i>Extract D</i> Contains most of alkaloids, quinine, strychnine, codeine, aconite, emetine (ipecac), cocaine.	<i>Solution D (Alkaline)</i> Shake with warm amyl alcohol to remove morphine.
				<i>Remaining solution</i> Test for coloring matters, glucose, sugar, gums, salts, etc.

Remarks:—Resinous and balsamic bodies are not very soluble in petrolic ether, but are more so in ordinary ether.

Cantharidin, in acid solutions, is much more soluble in chloroform than in ether.*

From acid solutions chloroform removes weak alkaloids (likewise oily and resinous bodies and glucosides not previously extracted).

From (ammoniacal) alkaline solutions chloroform removes most of the principal alkaloids except morphine which is more readily extracted with (hot) amyl alcohol.†

* See Prescott's Org. Anal., 1892, p. 83; also J.S.C.I., Vol. XXII, 1903,

Quassin, as well as hop bitters, is extracted by ether from acid solutions. Its best solvent is chloroform.* Resins of jalap, scammony, myrrh, senna and guiacum may be extracted from the dry material by a mixture of benzol (3), chloroform (2), and alcohol (1).†

A SCHEME FOR SEPARATING ALKALOIDS AND GLUCOSIDES ‡

(Based on Dragendorff's Method of Separation.)

The finely divided material is digested several hours with water acidulated with sulphuric acid, then filtered.

Filtrate:—Treat with magnesia (MgO), leaving slightly acid.

Evaporate to syrup, treat with 3 or 4 parts "70 per cent" alcohol acidulated with sulphuric acid, and digest 24 hours at 30° C. (frequent agitation). When cold filter and wash with alcohol. Evaporate to remove alcohol; then dilute with water.

Acid Aqueous Solution "A":—Treat with Petrolie Ether

<p><i>Solution "B" (petrolie ether)</i> Fats, oils, etc., bit- ters, piperin, sal- icylic acid.</p>	<p><i>Aqueous layer (acid)</i> Treat with benzol and test for extract. If any, nearly neutralize whole with MgO, leaving slightly acid, and repeat extraction with benzol.</p>		
<p>Petrolie ether does not remove alkalo- ids from acid solutions.</p>	<p><i>Solution C' (benzol)</i> Caffeine, colchicine, cubebine, digitalin, and traces of ber- berine, veratrine, etc.</p>	<p><i>Aqueous layer (still acid)</i> Extract with amyl alcohol.</p>	
		<p><i>Solution "D" (amyl al- cohol)</i> Berberine, cocaine, (?) picrotoxin, phy- sostigmine, theo- bromine, veratrine, cantharidine.</p>	<p><i>Aqueous layer (still acid)</i> Extract with chloro- form.</p> <p><i>Solution E (chloro- form)</i> May contain papave- rin, narcotine, the- baine, veratrine (some).</p>

* Comm. Org. Anal., 1896, Vol. III, part 3, pp. 187, 190.

† Comm. Org. Anal., 1896, Vol. III, part 3, p. 161.

‡ Consult Prescott's Prox. Org. Anal., 1892, pp. 124-128.

The Residual Aqueous Acid Layer Containing the Principal Alkaloids:— Make slightly *alkaline* with *ammonia* and treat with (first) petrolic ether to extract cocaine, emetine, quinine, conine, nicotine.* Follow with benzol for aconite, atropine, codeine, hyoscyamine, cinchonine, quinidine, strychnine, brucine, etc.† Finally, acidulate aqueous portion, wash with amyl alcohol, make alkaline with ammonia, and extract with warm amyl alcohol for morphine, etc.

Normal Acid and Alkali Solutions

NORMAL SULPHURIC ACID

A normal sulphuric acid solution should contain 49 grams H_2SO_4 , as such, per litre, based on the equivalent of one hydrogen atom, viz., one-half the molecular weight ($98 \times \frac{1}{2}$).

A normal solution of sodium carbonate would contain 53 grams Na_2CO_3 per litre and should neutralize exactly (cubic centimeter for cubic centimeter) a solution of H_2SO_4 containing 49 grams per litre.

It is impossible to weigh out exact quantity of H_2SO_4 , on account of its hygroscopic properties and variations in gravity. The gravity variations are, according to Blochmann's "Darstellung chemischer anorganischer Präparate," 1895, p. 75:

Gravity	Per cent H_2SO_4 by weight
1.820.....	90.0
1.825.....	91.0
1.830.....	92.0
1.835.....	93.5
1.840.....	96.0
1.8413.....	97.7
1.8412.....	98.0
1.8403.....	99.0
1.8384.....	100.0

* Consult Wells' Fres. Qual. Anal.

† Consult Fresenius' Qual. Anal.

The specific gravity of concentrated sulphuric acid increases up to a strength of 97.7 per cent; then slightly decreases as the maximum (100 per cent) is reached.

To prepare a normal solution of sulphuric acid, first prepare an approximate solution, preferably overstrength, so that it may be diluted to proper strength afterwards. Therefore, measure out about 30 c.c. C. P. sulphuric acid (sp. gr. 1.84 of 96 per cent strength) and dilute to 1000 c.c. for approximate normal strength.

Such a solution would contain about 53 grams of H_2SO_4 per litre:

$$30 \times 1.84 \text{ grams at } 15^\circ \text{ C.} = 55.2 \text{ grams.}$$

$$96 \text{ per cent of } 55.2 \text{ grams} = 52.99 \text{ grams } \text{H}_2\text{SO}_4.$$

To determine the amount of dilution required for normal strength, titrate the above solution against a known weight of C. P. dry sodium carbonate (made from sodium bi-carbonate, NaHCO_3), using methyl orange as an indicator.

The writer prefers to titrate two separate portions of C. P. dry Na_2CO_3 , each weighing exactly 2.65 grams, and theoretically equivalent to 50 c.c. normal acid solution. Dissolve each in 100 c.c. water.

Suppose that 2.65 grams are neutralized by 47.5 c.c. of the acid solution, then the acid is too strong and every 47.5 c.c. must be diluted to 50 c.c., or every 950 c.c. to 1000 c.c. for normal strength, thus:

$$47.5 : 50 = x : 1000. \quad (x = 950.)$$

If there is not enough solution to make one litre of normal acid, then calculate quantity necessary to make up, say, 900 c.c., thus:

$$47.5 : 50 = x : 900. \quad (x = 855.)$$

Then, measure out 855 c.c. in a graduated cylinder, if necessary, using a burette for the last 5 c.c., and dilute to 900 c.c. for a normal solution.

NORMAL HYDROCHLORIC ACID

Normal hydrochloric acid solution should contain 36.45 grams HCl as such per litre, and 100 c.c. of this should neutralize exactly 100 c.c. of normal Na_2CO_3 or NaOH solution.

As it is impossible to weigh the exact amount of HCl, take the gravity of C. P. muriatic acid by hydrometer, ascertain strength or per cent HCl from tables, and measure out sufficient acid to give slight overstrength when diluted to 1000 c.c. Titrate against C. P. Na_2CO_3 , as above.

For example, sp. gr. of acid = 1.165 = 33.02 per cent HCl. If 110 c.c. are taken, then $1.165 \times 110 \text{ c.c.} = 128.15$ grams acid. And 33.02 per cent of 128.15 grams = 42.31 grams HCl in the 110 c.c. acid taken. Suppose, on diluting this to 1000 c.c. and titrating, a strength of 41 grams HCl per litre is shown, then calculate the portion of this solution to take for dilution to normal, thus:

$$1000 : 41 = x : 36.45. \quad (x = 889.)$$

Therefore, take 889 c.c. of the overstrength solution and dilute to 1000 c.c.

NORMAL SODIUM HYDRATE

A normal solution of sodium hydrate contains 40 grams C. P. NaOH (caustic soda) per litre, each cubic centimeter being equivalent to, and neutralizing, one cubic centimeter of normal acid.

On account of its deliquescent properties, weigh out about 12 grams sodium hydrate — C. P. by alcohol — and

dissolve in about 400 c.c. distilled water. When cold dilute to 1000 c.c.

Titrate this solution against 50 c.c. normal sulphuric acid; that is, draw off 50 c.c. normal acid from a burette into a No. 2 beaker, dilute sufficiently with distilled water (which does not alter amount of acid in beaker), add a few drops methyl orange indicator, and titrate by "running in" the alkaline solution from a separate burette, finally drop by drop, with frequent stirring. End reaction: indicator changes from cherry-red (acid) to golden yellow (alkaline) the instant the point of neutrality is passed.

Phenol-phthalein indicator may likewise be used to advantage, colorless with acids but changing to crimson with alkalinity.

Suppose 46 c.c. of the alkaline solution exactly neutralizes 50 c.c. of the normal acid, then,

$$46 : 50 = x : 1000. \quad (x = 920.)$$

Therefore, take 920 c.c. of the sodium hydrate solution and dilute to 1000 c.c. for normal strength.

CARBONATE IN PRESENCE OF BI-CARBONATE

Solution, cold and dilute. For indicator, use phenol-phthalein which is neutral to bi-carbonates. Dip nose of burette into liquid and titrate with N/10 acid.

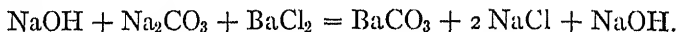
The neutral carbonate takes the acid first, forming bi-carbonate equivalent to $\frac{1}{2}$ carbonate.

Now, add a few drops methyl-orange indicator and titrate for total bi-carbonate.

Multiply first titration by two for carbonate, and deduct from final result for original bi-carbonate.

SMALL AMOUNTS OF CAUSTIC ALKALI WITH CARBONATE OR BI-CARBONATE

To a weighed sample in cold solution, add an excess of barium chloride:



The barium carbonate is neutral to phenol-phthalein; therefore, without filtering, titrate the cold solution direct for caustic alkali with N/10 acid.

For Carbonated Alkali:— Use separate weighed portion in cold solution, and titrate with N/10 acid for caustic and $\frac{1}{2}$ carbonate, using phenol-phthalein.

Then deduct equivalent caustic first found, and multiply the difference by 2 for carbonate. Complete titration, using methyl-orange indicator for other $\frac{1}{2}$ carbonate and any bi-carbonate originally present. From final number of c.c. acid used deduct the sum of equivalents for caustic and carbonate to obtain bi-carbonate.*

The Composition of Red Lead. (Pb_3O_4 .) Phillips states that Pb_4O_6 and not Pb_3O_4 is the formula for "red lead."

Percy† gives the following analysis, corresponding with the formula $4 \text{PbO} \cdot \text{PbO}_2$ or Pb_5O_6 .

	Per cent
Lead monoxide (PbO)	80.54
Lead dioxide (PbO_2)	18.89
Ferric oxide (Fe_2O_3)	0.19
	99.62

Hurst‡ indicates that both Pb_3O_4 and Pb_4O_6 are known, but that Pb_4O_6 can only be made by repeated oxidation of the monoxide, viz., litharge.

If Pb_3O_4 ($2 \text{PbO} \cdot \text{PbO}_2$) represents the "true red lead," then the higher 3 PbO or 4 PbO combinations must be

* See Sutton's Volumetric Analysis, 1890, p. 54.

† Metallurgy of lead.

‡ *Trans. Am. Chem. Soc.*, 1890, 12, 100.

due to the excess of litharge not entering the composition of the Pb_3O_4 .

Since litharge does not yield lead dioxide on treatment with dilute nitric acid, while "true red lead" does, then the dioxide produced ought to be the measure of the amount of Pb_3O_4 present. In other words, a sample of commercial red lead could yield an amount of dioxide proportional to the "true red lead" which it contains.

Multiplying the weight of dioxide obtained by a factor, 2.866, would give the "true red lead," as such, the difference between it and the weight of the original sample taken representing free litharge and impurities.

Woodman* adopted a method of digesting the sample with a saturated solution of lead acetate, which dissolves out the "free" litharge in excess of that combined as $2 \text{ PbO} \cdot \text{PbO}_2$. The separation is quite sharp, while prolonged digestion fails to produce any appreciable change in the weight of "true red lead."

If the nitric acid method of analysis is adopted to convert the red lead into the dark-brown peroxide, insoluble in nitric acid, and the monoxide which is soluble, it would be preferable to first remove the free litharge by the acetate method and determine its weight by loss.

Then treat the residue with dilute nitric acid to precipitate the peroxide (dioxide), whereby its equivalent in Pb_3O_4 is easily ascertained by the factor 2.866.

As an alternative method, the sample may be treated directly with dilute nitric acid to obtain the peroxide which is calculated to Pb_3O_4 , and the combined PbO determined by difference. Ascertain the total PbO in the acid solution by transposing to sulphate and calculating to monoxide. Deduct the combined PbO from the total PbO to find the free litharge.

* Jour. Am. Chem. Soc. 1897, p. 200.

Assuming either method to be carefully performed, any differences in the total weight of sample taken and the amounts of "true red lead" and "free" litharge, as found, must be due to other constituents as impurities.

It would be more satisfactory for commercial purposes to state an analysis as follows:

Obtained 18.89% PbO_2 (peroxide of lead)...	
True red lead equivalent (Pb_3O_4).....	54.14%
Free litharge (PbO).....	45.29%
Ferric oxide (Fe_2O_3).....	0.19%
Other impurities.....	0.38%
	<hr/> 100.00%

N.B. — True red lead does not produce a cement with glycerine, while litharge does.

INDEX

- Absinthin, 152.
Acetaldehyde, 3.
Acetanilid, 154-157.
Acetic anhydride, 14, 76, 127.
Acetone, 6, 72, 128.
Acetylation, 60.
Acid figure, 100.
 number, 58.
 number, total, 136.
 test, free, 71.
Acid, acetic, 13, 73, 95.
 arachidic, 77.
 benzoic, 32.
 boric, 69.
 carbolic, 18.
 cerotic, 131, 137, 139, 142.
 hydrochloric, 166.
 lauric, 131, 139.
 myristic, 131, 140.
 oleic, 89, 118.
 palmitic, 118, 119, 131, 139.
 quillajic, 151.
 salicylic, 69, 157.
 stearic, 118, 127, 130, 131,
 133, 138, 139.
 sulphuric, 164.
Acids, fatty, 94, 118, 121, 125.
 resin, 121.
Aconite, 146, 149, 161.
Acrolein, 10.
Action of nitric acid on oils, 75.
Adulterants of linseed oil, 98.
Adulterations in butter and milk,
 67.
Agar-agar, 34, 55.
Albertite, 42.
Albumenoids, 51, 52.
Alcohol, amyl, 13, 164.
 ceryl, 131, 141.
 cetyl, 131, 140.
 cholesteryl, 132, 141.
 ethyl, 6.
 methyl, 5.
 myricyl, 131, 137, 140.
 phytosteryl, 142.
Alkaloids, cadaveric, 144.
 dosage of, 147.
 separation of, 148, 163.
 solubilities of, 147, 149.
 vegetable, 144.
Aloins, 152.
Aluminum oleate, 112.
 palmitate, 112.
Amber, 36.
Amyl acetate, 13, 104.
Anilin, 16.
Approximate figures for oils, 66.
Asphalt, 41.
Atropine, 145, 149, 164.
Balsam, Canada, 29.
 copaiba, 30.
 Peru, 31.
 styrax, 30.
 tolu, 31.
Barfoed's test for glucose, 51.
Barium oleate, 119.
 palmitate, 119.
 stearate, 119.
Baudoin's test (sesamé oil), 76.
Beeswax, 123, 127-131, 136-138.
Benzine, 11.
Benzol, 16, 129, 163, 164.
Bitter principles, 151, 153, 154.

- Bitumens, 41.
- Blown oils, 81.
- Boiled oil, 103, 105, 106.
- Bone fat, 87.
 - tallow, 90.
 - tar, 19.
- Boric acid in milk, 69.
- Bromine absorption, 100-102.
- Butter, adulterations in, 67, 68.
- Cacao butter, 88.
- Caffeine, 144, 148, 149.
- Camphor, borneol, 24.
 - coal tar, 25.
 - laurel, 24.
 - menthol, 24.
 - peppermint, 24.
 - tonka bean, 28.
- Cantharidin, 162.
- Caoutchouc, 39.
- Caramel, 42.
- Carbohydrates, 42.
- Carbonates, 167, 168.
- Carbon bisulphide, 12.
 - tetrachloride, 8, 129, 135.
- Casein, 52.
- Cellulose, 47.
- Ceresin, 126, 131.
- Chiratin, 153.
- Chloral, 10.
- Chloroform, 8, 128, 147-149, 152, 162.
- Chocolate, 88.
- Cholesterol, 72, 132, 141, 142.
- Coal tar, 17.
- Cocaine, 144, 146, 147, 149, 150, 164.
- Collagens, 54.
- Colocynthin, 153.
- Colophonium, 38, 138.
- Comparisons of oils and fats, 81-89.
 - wax-like substances, 138.
- Convolvulin, 152.
- Copal, gum, 34.
 - Manila, 35,
- Copal, Demerara, 35.
- Copper resinate, 117.
 - soap, 110.
- Cresote, beechwood, 18, 19.
 - coal tar, 19.
 - oils, 17.
- Cumarin, 28.
- Degras, 124.
- Dextrin, 46.
- Dextrose, 43.
- Digitalin, 151.
- Driers, determination of, 106.
 - proportion of, 104.
- Drying test, 74.
- Elaidin test, 78-80.
- Essential oils, 25.
- Ester number, 58.
- Ether, ethyl, 11, 128, 147, 149, 161.
 - petrolie, 11, 72, 128, 147, 149, 150, 162-164.
- Fatty acids, melting-point of, 120.
 - separation of, 118.
- Fehling's solution, 48, 49.
- Flash-point, 71.
- Formal, 1.
- Formaldehyde, 1, 2.
- Free acid test, 71, 94.
- Froehde's reagent, 150.
- Furfural, 4.
- Fusel oil, 12, 129.
- Gasoline, 11, 72, 93, 95, 107, 108, 109.
- Gas tar, 17.
- Gelatine, 54.
- Gentiopierin, 153.
- Gilsonite, 42.
- Glacial acetic acid, 13, 73, 95.
- Glucose, 43.
- Glucosides, 151.
- Glue, common, 55.
 - fish, 54,

- Gluten, 53.
Glycerides, 56.
Glycerine, 14.
 analysis of, 62.
Grahamite, 42.
Greases, analysis of, 93-96.
 composition of, 92.
 rosin oil in, 92, 95.
Group table for oils, 89.
Gum arabic, 34.
 benzoin, 31.
 chicle, 41.
 copal, 34.
 damar, 34, 35.
 kauri, 34, 35.
 mastic, 37.
 resins, 33.
 sandarac, 37.
 tragacanth, 34.
Gumming test, 74.
Gun cotton, 48.
• Gutta percha, 40.

Hair tonics, analysis of, 162.
Halphen's reaction (cottonseed oil),
 75.
Hanus' solution, 67.
Hexabromide test, 75, 97.
Higher alcohols, 139.
Hop bitters, 153.
Horse fat, 90.
Hübl method, 62, 64, 100.
Hydrocarbons in waxes, 134.
Hydrochloric acid, normal, 166.

Immiscible solvents, 148, 161.
Iodine absorption, 62.
Iodoform test, 6.
Iron resinate, 117.
 soap, 110.
Isinglass, 54.
Isocholesterol, 132, 142.
Isonitril test, 154-156.

Jalapin, 152.
Japan wax, 88, 122, 127-131, 133,
 138, 143.
Koettstorfer process, 57.

Lactose, 44.
Lanolin, 125, 131.
Lard, 87.
Lead arachidate, 118.
 hypogaeate, 118.
 laurate, 118.
 linoleate, 113.
 myristate, 118.
 oleate, 111, 118.
 palmitate, 112, 118.
 resinate, 115-117.
 ricinolate, 118.
 stearate, 112, 118.
Levulose, 43.
Liebermann-Storch reaction, 76, 96.
Linoleates, insoluble, 112-114.
Livache test, 74, 100.
Lubricating oils, 90-96.
Luster work, 117.

Magnesium oleate, 119.
 palmitate, 119.
 stearate, 119.

Malt, 44.
Maltose, 44.
Manganese linoleate, 113.
 resinate, 115, 116.
Maumené test, 72, 100.
Melting-point, 70, 120.
Menthol, 24.
Methylal, 1.
Milk, boric acid in, 60.
 salicylic acid in, 60.
 sugar, 44.
Mixed fatty and resin acids, 121.
Moisture in oils, 71, 93.
Molasses, 44.
Morphine, 144, 145, 148, 149, 161, 164.
Myricin, 137, 142.

- Naphtha, 17.
 Naphthalene, 17, 25.
 Nitric acid tests, 75.
 Nitro-benzol, 16.
 Non-glucosides, 152.
 Non-glycerides, 56.
 Non-saponifiable matter, 55, 72,
 100, 125.
 Oil, almond (sweet), 81, 89.
 anise, 26.
 anthracene, 17.
 arachis, 81.
 bergamot, 26.
 bitter almonds, 27.
 blown, 81, 89.
 boiled, 103.
 castor, 81, 89.
 China-wood, 76, 83.
 cinnamon, 28.
 citronella, 26.
 cloves, 27.
 cocoanut, 84.
 cod-liver oil, 85.
 colza, 82.
 corn, 82, 89.
 cottonseed, 82, 89.
 creosote, 17.
 croton, 83, 89.
 fish, 75, 97, 98.
 lard, 85, 89.
 lavender, 25.
 lemon, 26.
 lemon grass, 26.
 linseed, 75, 83, 89, 97, 103.
 maize, 82.
 menhaden, 86, 89, 98.
 mineral, 55, 73, 74, 89, 92, 95, 98.
 neatsfoot, 85, 89.
 olive, 82, 89.
 palm, 84.
 peanut, 81, 89.
 peppermint, 24.
 pennyseed, 82, 89.
 Oil, rape, 82, 89.
 rosin, 73, 76, 89, 91, 95, 99.
 sassafras, 27.
 sesamé, 83, 89.
 soya bean, 84.
 sperm, 86, 89, 90, 124.
 sunflower, 84, 89.
 tallow, 85, 89.
 tung, 74, 83, 89.
 turpentine, 22, 99, 129.
 whale, 86.
 wintergreen, 27.
 Oils, commercial tests on, 69-80.
 comparisons of, 81-89.
 lubricating, 90-96.
 table of, 66, 89.
 vegetable, 81-84.
 Oleates, preparation of, 111.
 Oleomargarine, 68.
 Opodeldoc, 111.
 Ozocerite, 126.
 Paint analysis, 107.
 Palmitates, preparation of, 111.
 Paraffin, 55, 122, 126-133, 138.
 Pavy's solution, 50.
 Pectin, 34.
 Petrolie ether, 11, 72, 128, 147-149,
 162 164.
 Phenacetin, 154 156.
 Phenol, 18.
 Phospho-molybdate reagent, 150.
 Phytosterol, 132, 142.
 Picrotoxin, 152, 162, 163.
 Pitch, Burgundy, 38.
 coal tar, 17, 41.
 pine, 39.
 Proteids, 51.
 Proteoids, 54.
 Ptomaines, 144.
 Pyridin, 21.
 Pyroxylin, 48, 104.
 Pyrrol, 20.

- Quassin, 153, 163.
 Quinine, 144, 145, 149, 164.
 Raffinose, 44.
 Reactions, saponification, 56.
 Reagents, alkaloidal, 149, 150.
 Red lead, composition of, 168.
 Reichert process, 59.
 Renard's test (peanut oil), 77.
 Resin acids, mixed fatty and, 121.
 Resinates, 114-117.
 Resins, gum, 33.
 Rosin, common, 38, 132, 138.
 oil, 73, 76, 89, 91, 95.
 soap, 114.
 Rubber gum, 39.
 substitutes, 40.
 Salicin, 151.
 Salicylic acid, 69, 157.
 Santonin, 152.
 Saponin, 151.
 Saponification, 55, 74.
 Sarsaparillin, 152.
 Scammonin, 152.
 Scheme, organic substances, 161, 163.
 Shellac, 35.
 Sitosterol, 142.
 Soap, aluminum, 110.
 copper, 110, 117.
 iron, 110, 117.
 magnesium, 109.
 marine, 110.
 tin, 110.
 zinc, 110.
 Soaps, insoluble, 93, 109.
 in greases, 92, 94.
 Sodium hydrate, normal solution, 166.
 laurate, 84.
 linoleate, 112.
 nitroprusside, 159.
 resinate, 114.
 thiosulphate (standard), 63, 64.
 Solidification-point, 70.
 Solubilities, alkaloids, 147, 150.
 waxes, 127.
 Solubility tests, oils, 72.
 Specific gravity, 70, 130.
 Spermaceti, 123, 127-131, 133, 138.
 Starch, 45, 132.
 Stearates, preparation of, 111.
 Stearic acid, 118, 127, 131, 133, 138, 139.
 Stearin, 57, 87, 127, 130.
 cottonseed, 88.
 Strophanthin, 152.
 Strychnine, 144, 146-148, 149, 164.
 Sugar, beet, cane, maple, 42.
 fruit, 43.
 invert, 42.
 milk, 44.
 Sulphur chloride, 12.
 in waxes, 132.
 Sulphuric acid, normal, 164.
 Table, approximate figures, 66.
 comparisons of oils, 81-89.
 group, for oils, 89.
 solubilities of alkaloids, 147-149.
 vegetable alkaloids, 144-146.
 wax-like substances, 138.
 Tallow fat, 87.
 Tar, coal, 41.
 pine, 39.
 wood, 38.
 Test for cottonseed oil, 75.
 fish oils, 75, 97, 98.
 linseed oil, 75, 99.
 peanut oil, 77.
 rosin oil, 76, 99.
 sesamé oil, 76, 77.
 Tests on acetanilid, 154-157.
 acetone, 3, 6.
 alcohols, 6.
 aldehydes, 2-5, 7, 8

- Tests on alkaloids, 149, 150.
 balsams, 32.
 bitter principles, 154.
 carbon tetrachloride, 9.
 chloral, 10.
 chloroform, 9.
 cholesterol, 141.
 furfural, 5.
 glycerine, 15.
 morphine, 149, 150.
 oils and fats, 69-80.
 phenacetin, 154-156.
 phenol, 18.
 phytosterol, 142.
 quassin, 154.
 quinine, 149, 150, 155, 157.
 salicin, 154.
 salol, 155, 156.
 strychnine, 149, 150.
 sugar, 48-51.
 waxes, 132-138, 143.
 Thalleioquin test, 157.
 Tocher's test (sesamé oil), 77.
 Toluol, 16.
 Total acid number, 136.
 True gums, 33, 34.
 Turpentine, 22, 99, 129.
 Venice, 23.
 Unsaponifiable matter, 55, 72, 100, 125.
 Valenta turbidity test, 73.
 Vanilla, 29.
 Vaseline, 126.
 Viscosity, 69.
 Wax acids, 139.
 alcohols, 139.
 bayberry, 123.
 bees, 123, 127-138, 142.
 carnauba, 123, 127-138.
 Chinese, 123.
 decomposed, 136, 137.
 Japan, 88, 122, 127-138, 143.
 mineral, 126.
 myrtle, 123.
 paraffin, 122, 126, 127-138.
 spermaceti, 123, 127-133, 138.
 Waxes, comparisons on, 138.
 hydrocarbons in, 134.
 melting-points of, 131.
 mixed, 133.
 saponification of, 134.
 solubility of, 127-129.
 specific gravity of, 130.
 tests on, 132, 133, 143.
 Wijs' solution, 65.
 Wood alcohol, 5.
 tar, 17, 38.
 Wool fat, 124.
 grease, 124.

A CATALOGUE
OF
TECHNICAL AND
SCIENTIFIC BOOKS
PUBLISHED BY
CONSTABLE
& COMPANY LTD





CONSTABLE & COMPANY LTD

TECHNICAL & SCIENTIFIC BOOKS

CONTENTS

	PAGE
Aeronautics	19
Agriculture and Farming	55
Arts and Crafts	51
Chadwick Library, The	2
Civil Engineering, Building Construction, etc.	27
D.-S. Technical Dictionaries, The	7
Electrical Engineering	34
Electro-Chemistry, etc.	38
Encyclopædia of Municipal and Sanitary Engineering	5
Fuel and Smoke	12
Glasgow Text-books of Civil Engineering	4
Internal Combustion Engines	8
Iron, Steel, and other Metals	17
Irrigation and Water Supply	31
Law, Patents, etc.	56
Lighting	38
Machinery, Power Plants, etc.	13
Manufacture and Industries	48
Marine Engineering	21
Mathematics	47
Metallurgy	3
Mining	23
Miscellaneous	57
Motor Cars and Engines	18
Municipal Engineering	30
Natural History, Botany, Nature Study, etc.	53
Outlines of Industrial Chemistry	2
Physics and Chemistry	40
Practical Manuals for Practical Men	3
Pumps	16
Railway Engineering	24
Reinforced Concrete and Cement	25
Steam Engines, Boilers, etc.	10
Surveying, etc.	29
Telegraphy and Telephony	32
Thermodynamics	39
Thresholds of Science	5
Turbines and Hydraulics	22
Useful Handbooks and Tables	52
"Westminster" Series, The	6
Index	60

Outlines of Industrial Chemistry

A SERIES OF TEXT-BOOKS INTRODUCTORY TO
THE CHEMISTRY OF THE NATIONAL INDUSTRIES.

EDITED BY

GUY D. BENGOUGH, M.A., D.Sc.

An Introduction to the Study of Fuel.

By F. J. Brislee, D.Sc.

With many Illustrations. Demy 8vo. 8/6 net. (See p. 12.)

The Chemistry of Dyeing and Bleaching of Vegetable Fibrous Materials.

By Julius Hübner, M.Sc.Tech., F.I.C.

Demy 8vo. Illustrated. 14/- net. (See p. 45.)

The Chemistry of the Rubber Industry.

By Harold E. Potts, M.Sc. *Demy 8vo. 5/- net. (See p. 46.)*

Iron and Steel. An Introductory Textbook for Engineers and Metallurgists.

By O. F. Hudson, M.Sc., A.R.C.S., and Guy D.
Bengough, M.A., D.Sc. *Demy 8vo. Illustrated. 6/- net. (See
p. 17.)*

The Chemistry of the Oil Industry.

By J. E. Southcombe, M.Sc., F.C.S. *Demy 8vo. Illustrated,
7/6 net. (See p. 48.)*

Cement, Concrete, and Bricks. By A. B. Searle.

Demy 8vo. Illustrated. 8/6 net. (See p. 46.)

OTHER VOLUMES IN PREPARATION.

The Chadwick Library.

Rainfall, Reservoirs and Water Supply.

By Sir Alexander Binnie. *8/6 net. (See p. 30.)*

Vital Statistics Explained.

By Joseph Burn, F.I.A., F.S.I. *4/- net. (See p. 58.)*

IN PREPARATION.

Altitude and Health.

By Prof. F. F. Roget.

OTHER VOLUMES WILL FOLLOW.

Metallurgy

Edited by WALTER ROSENHAIN, F.R.S., B.Sc., etc.

An Introduction to the Study of Physical Metallurgy.

By G. Walter Rosenhain, B.A., D.Sc., F.R.S. 10/6 net.
(See p. 41.)

IN PREPARATION.

The Metallurgy of Brass.

By G. D. Bengough, M.A., D.Sc.

The Metallurgy of Zinc.

By J. S. G. Primrose, A.R.T.C., A.I.M.M.

The Metallurgy of Aluminium.

By R. Seligman, Ph.Nat.D.

The Metallurgy of Strain.

By J. C. W. Humfrey, B.A., M.Sc.

The Metallurgy of Refractory Metals.

By W. C. Hancock, B.A., F.I.C.

Practical Manuals for Practical Men

Fully Illustrated and Indexed.

Foundations and Machinery Fixing. By Francis H. Davies. 2/- net.
(See p. 28.)

ELECTRIC WIREMEN'S MANUALS.

Testing and Localizing Faults. By J. Wright. 1/- net.

Arc Lamps and Accessory Apparatus. By J. H. Johnson, A.M.I.E.E.
1/6 net.

Motors, Secondary Batteries, Measuring Instruments and Switchgear. By S. K. Broadfoot, A.M.I.E.E. 1/- net.

Mill and Factory Wiring. By R. G. Devey. 2/- net.

Electric Mining Installations. By P. W. Freudemacher, A.M.I.E.E.
2/- net.

Ship Wiring and Fitting. By T. M. Johnson. 1/- net.

Bells, Indicators, Telephones, Alarms, etc. By J. B. Redfern and J. Savin. 1/6 net.

Switchgear and the Control of the Electric Light Power Circuits.
By A. G. Collis, A.M.I.E.E. 1/- net.

The Glasgow Text-Books of Civil Engineering

Edited by **G. MONCUR, B.Sc., M.Inst.C.E.**, Professor of
Civil Engineering at the Royal Technical College, Glasgow.

Railway Signal Engineering (Mechanical).

By **Leonard P. Lewis**, of the Caledonian Railway ;
Lecturer on Railway Signalling at the Royal Technical
College, Glasgow. *Illustrated. Demy 8vo. 8/- net. (See p. 25.)*

Modern Sanitary Engineering.

By **Gilbert Thomson, M.A., F.R.S.E., M.Inst.C.E.**

Part I. : House Drainage. *Illustrated. Demy 8vo. 6/- net. (See
p. 31.)*

Part II. : Sewerage.

Reinforced Concrete Railway Structures.

By **J. D. W. Ball, A.M.Inst.C.E.**

Illustrated. Demy 8vo. 8/- net. (See p. 24.)

Surveying and Field Work. By **J. Williamson,**
A.M.Inst.C.E. *Demy 8vo. 7/6 net. (See p. 29.)*

IN PREPARATION.

Surveying and Geodesy for Engineers. By **David
Clark, B.Sc. (Lond. Hon.), A.M.Inst.C.E.**, Lecturer on Surveying
in the Royal Technical College, Glasgow.

Foundations. By **W. Simpson, M.Inst.C.E.**

Earthwork. By **J. W. F. Gardner, M.Inst.C.E.**

Railway Permanent Way. By **W. A. Messer, A.M.Inst.C.E.**

Bridge Work. By **William Burnside, A.M.Inst.C.E.**

Equipment of Docks. By **W. H. Hunter, M.Inst.C.E.**

Materials of Construction. By **Nathaniel Martin, A.R.T.C.**

Tunnelling. By **James Forgie. (U.S.A.)**

Pipe Lines. By **Prof. W. F. Durand. (U.S.A.)**

Iron and Steel Alloys. By **A. Campion, F.I.C. and William
C. Gray.**

Ventilating and Heating. By **D. D. Kimball. (U.S.A.)**

Caisson Construction.

Municipal Engineering.

THE ENCYCLOPÆDIA OF MUNICIPAL AND SANITARY ENGINEERING.

EDITED BY

W. H. MAXWELL, A.M.Inst.C.E.

Borough and Waterworks Engineer, Tunbridge Wells Corporation, etc.

In one volume.

Cloth. Price 42/- net.

Among the many Contributors to this exhaustive work are:—

ADAMS, Professor HENRY, M.Inst.C.E., M.I. Mech.E., F.S.I., F.R.San.I.
ANGEL, R. J., M.Inst.C.E., A.R.I.B.A., Borough Engineer and Surveyor, Bermondsey.
BURNIE, E. LANCASTER, A.M.Inst.C.E., A.M.I. Mech.E., Consulting Engineer.
CHAMBERS, SIDNEY H., Surveyor, Hampton Urban District Council.
DIBBIN, W. J., F.I.C., F.C.S., formerly Chemist and Superintending Gas Engineer, London County Council.
FIRTH, Lieut.-Col. R. H., R.A.M.C.
FOWLER, Dr. GILBERT J., F.I.C., Consulting Chemist to the Manchester Corporation Rivers Committee.
FREEMAN, ALBERT C., M.S.A.
FREEMAN, W. MARSHALL, of the Middle Temple, Barrister-at-Law.
FRETWELL, W. E., Lecturer on Plumbing and Sanitary Science, L.C.C. School of Building.
GARFIELD, JOSEPH, A.M.Inst.C.E., Sewerage Engineer, Bradford.
HART, GEORGE A., Sewerage Engineer, Leeds.
HOBART, H. M., M.Inst.C.E., M.I.E.E., etc.

JENNINGS, ARTHUR SEYMOUR, Editor of *The Decorator*.
JENSEN, GERARD J. G., C.E., Consulting Engineer.
KENWOOD, H. R., M.B., B.S., D.P.H., Professor of Hygiene and Public Health, University College, London.
LATHAM, FRANK, M.Inst.C.E., Borough Engineer and Surveyor, Penzance.
MARTIN, ARTHUR J., M.Inst.C.E., Consulting Engineer.
MOOR, C. G., M.A., F.I.C., F.C.S., Public Analyst for the County of Dorset and the Borough of Poole.
OWENS, Dr. JOHN S., A.M.Inst.C.E.
PARTRIDGE, W., F.I.C.
PORDAGE, A., Firemaster, City of Edinburgh.
RIDEAL, S., D.Sc. Lond., F.I.C., F.R.San.I.
THRESH, JOHN C., M.D., D.Sc., Medical Officer of Health for the County of Essex.
THUDICUM, GEORGE, F.I.C.
WATSON, JOHN D., M.Inst.C.E., Engineer to the Birmingham, Tame and Rea District Drainage Board.
WEBBER, W. H. Y., C.E., Consulting Engineer.

Thresholds of Science.

A NEW SERIES OF HANDY SCIENTIFIC TEXT-BOOKS, WRITTEN
IN SIMPLE, NON-TECHNICAL LANGUAGE, AND ILLUSTRATED
WITH NUMEROUS PICTURES AND DIAGRAMS.

Cr. 8vo. 2/- Net per Vol.

Mechanics. By C. E. Guillaume. 200 + xiii pages. 50 illustrations.

Chemistry. By Georges Darzens. 122 + x pages. 31 illustrations.

Botany. By E. Brucker. 185 + xv pages. 235 illustrations.

Zoology. By E. Brucker. 219 + xiii pages. 165 illustrations.

Mathematics. By C. A. Laisant. 158 + viii pages. Over 100 illustrations.

Astronomy. By Camille Flammarion. 191 + xi pages. 184 illustrations.

The "Westminster" Series

Uniform. Extra Crown 8vo. Fully Illustrated. 6/- net each.

- Soils and Manures. By J. ALAN MURRAY, B.Sc.
The Manufacture of Paper. By R. W. SINDALL, F.C.S.
Timber. By J. R. BATERDEN, A.M.I.C.E.
Electric Lamps. By MAURICE SOLOMON, A.C.G.I., A.M.I.E.E.
Textiles and their Manufacture. By ALDRED BARKER, M.Sc.,
Technical College, Bradford.
The Precious Metals: comprising Gold, Silver, and Platinum.
By THOMAS K. ROSE, D.Sc., of the Royal Mint.
Decorative Glass Processes. By A. L. DUTHIE.
The Railway Locomotive. By VAUGHAN PENDRED, late Editor
of *The Engineer*.
Iron and Steel. By J. H. STANSBIE, B.Sc. (Lond.), F.I.C.
Town Gas for Lighting and Heating. By W. H. Y.
WEBBER, C.E.
Liquid and Gaseous Fuels, and the Part they play in
Modern Power Production. By Professor VIVIAN B.
LEWES, F.I.C., F.C.S., Prof. of Chemistry, Royal Naval College, Greenwich.
Electric Power and Traction. By F. H. DAVIES, A.M.I.E.E.
Coal. By JAMES TONGE, M.I.M.E., F.G.S., etc. (Lecturer on
Mining at Victoria University, Manchester).
India-Rubber and its Manufacture, with Chapters on
Gutta-Percha and Balata. By H. L. TERRY, F.I.C.,
Assoc.Inst.M.M.
The Book: Its History and Development. By CYRIL
DAVENPORT, F.S.A.
Glass Manufacture. By WALTER ROSENHAIN, Superintendent
of the Department of Metallurgy in the National Physical Laboratory.
The Law and Commercial Usage of Patents, Designs, and
Trade Marks. By KENNETH R. SWAN, B.A.(Oxon.), of the
Inner Temple, Barrister-at-Law.
Precious Stones. With a chapter on Artificial Stones.
By W. GOODCHILD, M.B., B.Ch.
Electro-Metallurgy. By J. B. C. KERSHAW, F.I.C.
Natural Sources of Power. By ROBERT S. BALL, B.Sc.,
A.M.I.C.E.
Radio-Telegraphy. By C. C. F. MONCKTON, M.I.E.E.
Introduction to the Chemistry and Physics of Building
Materials. By ALAN E. MUNBY, M.A. (Cantab.).
The Gas Engine. By W. J. MARSHALL, A.M.I.M.E., and
Captain H. RIAL SANKEY, R.E., M.I.C.E.
Photography. By ALFRED WATKINS, Past-President of the
Photographic Convention, 1907.
Wood Pulp. By CHARLES F. CROSS, B.Sc., F.I.C., E. J. BEVAN,
F.I.C., and R. W. SINDALL, F.C.S.
Welding and Cutting of Metals by the Aid of Gases or
Electricity. By DR. L. A. GROTH.
General Foundry Practice. By WILLIAM ROXBURGH.
Commercial Paints and Painting. By ARTHUR SEYMOUR
JENNINGS.

A Series of Technical Dictionaries in Six Languages.

The D.-S. Series of Technical Dictionaries in Six Languages.

English. Spanish. German. Russian. French. Italian.

With each word, term, or item, so far as it is possible, a diagram, formula, or symbol is given, so that error or inaccuracy is almost impossible.

VOL. I.—The Elements of Machinery and the Tools most frequently used in Working Metal and Wood. *Price 5/- net, cloth ; 7/6 net, leather.*

VOL. II.—Electrical Engineering, including Telegraphy and Telephony. *Price 25/- net, cloth ; 30/- net, leather.*

VOL. III.—Steam Boilers and Steam Engines. *Price 16/- net, cloth ; 20/- net, leather.*

VOL. IV.—Internal Combustion Engines. *Price 8/- net, cloth ; 10/6 net, leather.*

VOL. V.—Railway Construction and Operation. *Price 12/- net, cloth ; 16/- net, leather.*

VOL. VI.—Railway Rolling Stock. *Price 10/6 net, cloth ; 14/- net, leather.*

• **VOL. VII.—Hoisting and Conveying Machinery.** *Price 10/6 net, cloth ; 14/- net, leather.*

VOL. VIII.—Reinforced Concrete in Sub- and Superstructure. *Price 6/- net, cloth ; 8/6 net, leather.*

VOL. IX.—Machine Tools (Metal Working ; Wood Working). *Price 9/- net, cloth ; 12/6 net, leather.*

VOL. X.—Motor Vehicles (Motor Cars, Motor Boats, Motor Air Ships, Flying Machines). *Price 12/- net, cloth ; 16/- net, leather.*

VOL. XI.—Metallurgy. *Price 10/6 net, cloth ; 14/- net, leather.*

IN PREPARATION:—Vol. XII.—Hydraulics.

Vol. XIII.—Ironwork Construction.

SOME PRESS OPINIONS:

"We heartily recommend the work to all who have occasion to read foreign articles on engineering."—*Mining Engineering.*

"The best book, or series of books, of its kind yet attempted."—*The Engineer.*

"These Dictionaries are the best of the kind yet attempted, and their arrangement and design leave nothing to be desired."—*Surveyor.*

"Anyone desiring a Technical Dictionary for a foreign language will find this the most comprehensive and explicit that has ever been issued."—*Mechanical Engineer.*

Detailed Prospectus post free.

Internal Combustion Engines.

Internal Combustion Engines

The Internal Combustion Engine : Being a Text-Book on Gas, Oil, and Petrol Engines, for the use of Students and Engineers. *2nd Edition. Revised and Enlarged.*

By **H. E. Wimperis, M.A., A.M.Inst.C.E., A.M.I.E.E.**
Illustrated. Demy 8vo. 6/6 net.

A Primer of the Internal Combustion Engine.

By **H. E. Wimperis, M.A., A.M.Inst.C.E., etc.** *2/6 net.*

The Design and Construction of Internal Combustion Engines : A Handbook for Designers and Builders of Gas and Oil Engines.

By **Hugo Güldner.** Translated from the Second Revised Edition, with additions on American Engines, by **H. Diederichs**, Professor of Experimental Engineering, Cornell University. *Imperial 8vo. Illustrated. 42/- net.*

The Construction and Working of Internal Combustion Engines.

BEING A PRACTICAL MANUAL FOR GAS ENGINE DESIGNERS, REPAIRERS AND USERS. By **R. E. Mathot.** Translated by **W. A. Tookey.** *Medium 8vo. With over 350 Illustrations. 24/- net.*

The Diesel Engine for Land and Marine Purposes. *4th Edition, revised and brought up to date. Illustrated.*

By **A. P. Chalkley, B.Sc., A.M.Inst.C.E., A.I.E.E.**
Demy 8vo. 8/6 net.

CONTENTS.—Introduction. General Theory of Heat Engines, with Special Reference to Diesel Engines. Action and Working of the Diesel Engine. Construction of the Diesel Engine. Installing and Running Diesel Engines. Testing Diesel Engines. Diesel Engines for Marine Work. Construction of the Diesel Marine Engine. The Future of the Diesel Engine. Appendix. Index.

Internal Combustion Engines—continued.

High Power Gas Engines.

By **H. Dubbel**. Translated, edited and expanded to include British Engines and Practice, by **F. Weinreb**.

197 + xii pages. 436 Illustrations. 18/- net.

CONTENTS: Author's Preface. Translator's Preface. The Cycle of the Gas Engine. Output and Cylinder Dimensions. The Governing of the Four-Cycle Engines. Valve Gear of Four-Cycle Engines. The Two-Cycle Engine. Valve Gears. Ignition. The Cylinders. Valves and their Cooling. Pistons and their Cooling. Stuffing Boxes. General Design of Principal parts. Calculation of the Flywheel Weight. Starting. Piping.

The Gas Turbine. By **Norman Davey**.

248 + xiv. pages. 100 Illustrations. Demy 8vo. 15/- net.

CONTENTS.—THE THEORY: General Considerations of the Gas Turbine as a Heat Engine. The Constant Pressure, Single-Fluid Gas Turbine. Mixed-Fluid Turbines; Derived Types. The "Explosion" Gas Turbine. The Variation in Thermodynamic Constants and its Effect upon Efficiency. THE PRACTICE: Accessory Machinery. Practical Limitations. Summary of Efficiencies and Comparison of Types. The History of the Gas Turbine. The Progress in Experimental Work. The Future of the Gas Turbine. APPENDIX: List of Gas Turbine Patents, 1856-1913. Index.

The Gas Engine.

By **W. J. Marshall, A.M.I.M.E., and Captain H. Riall Sankey, late R.E., M.I.M.E., etc.**

Illustrated. Extra Crown 8vo. 6/- net.

CONTENTS.—Theory of the Gas Engine. The Otto Cycle. The Two-Stroke Cycle. Water Cooling of Gas Engine Parts. Ignition. Operating Gas Engines. Arrangement of a Gas Engine Installation. The Testing of Gas Engines. Governing. Gas and Gas Producers.

The Energy-Diagram for Gas. By **F. W. Burstall**,

M.A., Chance Professor of Mechanical Engineering in the University of Birmingham.

With Descriptive Text. 5/- net. The Diagram sold separately, 2/- net.

American Gas-Engineering Practice.

By **M. Nisbet-Latta**, Member American Gas Institute, M.Am.Soc.M.E.

460 pages and 142 illustrations. Demy 8vo. 18/- net.

Gas Engine Design.

By **Charles Edward Lucke, Ph.D.,** Mechanical Engineering Department, Columbia University, New York City.

Illustrated with numerous Designs. Demy 8vo. 12/6 net.

Gas Engine Construction.

Second Edition.

By **Henry V. A. Parsell, Jr., M.A.I.E.E., and Arthur J. Weed, M.E.** *Illustrated. 304 pages. Demy 8vo. 10/6 net.*

Gas and Gas Engines—continued.

Gas, Gasoline, and Oil Engines, including Gas Producer Plants.

By **Gardner D. Hiscox, M.E.**, Author of "Mechanical Movements," "Compressed Air," etc.

Illustrated. Demy 8vo. 10/6 net. Tenth Edition largely rewritten and brought up to date. By Victor W. Page, M.I.

Probably the most comprehensive work on the subject.

British Progress in Gas Works Plant and Machinery.

By **C. E. Brackenbury, C.E.**, Author of "Modern Methods of Saving Labour in Gas Works."

Illustrated. Super-Royal 8vo. 6/- net.

Town Gas and its Uses for the Production of Light, Heat, and Motive Power.

By **W. H. Y. Webber, C.E.**

With 71 Illustrations. Ex. Crown 8vo. 6/- net.

Steam Engines, Boilers, etc.

A Manual of the High-Speed Steam Engine.

By **H. Keay Pratt, A.M.I.Mech.E.**

About 250 pages. Illustrated. Demy 8vo. 5/- net.

CONTENTS:—I. History and General Remarks. II. Steam Cylinders and Adjuncts. III. Valves. IV. Pistons. V. Piston-rods, Crank-shafts, etc. VI. Baseplates. VII. Governors. VIII. Cast-iron and other details. IX. Indicator-Cards and Effort Diagrams. X. Testing. XI. Foundations, Pipe Connections, etc. XII. Practical Notes on the Working of High-Speed Engines. XIII. A Description of Various Engines. Index.

The Modern Steam Engine: Theory, Design, Construction, Use.

By **John Richardson, M.Inst.C.E.**

With 300 Illustrations. Demy 8vo. 7/6 net.

This is a thoroughly practical text-book, but it will also commend itself to all who want to obtain a clear and comprehensive knowledge of the steam engine.

The Una-flow Steam Engine.

By **J. Stumpf. Illustrated. 10/6 net.**

Boiler Explosions, Collapses, and Mishaps.

By **E. J. Rimmer, B.Sc., etc. Demy 8vo. 4/6 net.**

Steam Engines, Boilers, etc.—continued.

The Steam Engine and Turbine.

By **Robert C. H. Heck, M.E.** *Demy 8vo. 20/- net.*

Test Methods for Steam Power Plants. A refer-

ence book for the use of Power Station Engineers, Superintendents, and Chemists. By **E. H. Tenney, B.A., M.E.**

Ex. Crown 8vo. 85 Illustrations. 10/6 net.

CONTENTS:—Purchase and Testing of Coal. Investigation of the Economy of Combustion. Treating and Testing Water for Boiler-feed Purposes. Evaporating Tests. Testing Prime Movers. Power Plant Lubricants.

Engine Tests and Boiler Efficiencies.

By **J. Buchetti.** Translated and Edited from the 3rd Edition by **Alexander Russell, M.I.E.E., etc.**

Illustrated. Demy 8vo. 10/6 net.

Boiler Draught. By **H. Keay Pratt, A.M.I.M.E.**

Illustrated. Crown 8vo. 4/- net.

CONTENTS:—Draught. Calculations relating to Air. Chimneys. Construction. Artificial Draught. Forced Draught. Induced Draught. A Comparison. The Application of Mechanical Draught for Land Installations. The Application of Mechanical Draught in Marine Practice. The Chemistry of Combustion. Index.

Marine Double-ended Boilers. By **John Gray.**

Illustrated. Crown 8vo. 3/6 net.

LIST OF TABLES:—Thicknesses and Working Pressure of Front Tube Plate at wide Water Space. Top End Plates; Surfaces supported in Square Inches. Combustion Chamber Plates; Surfaces supported in Square Inches. Top End Plate Stays; Surfaces supported in Square Inches. Combustion Chamber Stays. Surfaces supported in Square Inches. Areas and Circumference of Circles in Feet and Inches. Areas of Rivets in Square Inches. Areas of Small Circles in Square Feet. Effective Sectional Area of Stays. Effective Sectional Area of Stay Tubes. Area through Tubes in Square Inches and Square Feet. Grate Area of Furnaces in Square Feet. Heating Surface of Boiler Tubes in Square Feet. Dimensions of Back End of Furnaces. Rivet Spacing Table. Weight of Steel Plates in Pounds per Square Foot. Boiler Stay Nuts. Maximum Pitches (Double Butt Straps). Weight of Iron Tubes in Pounds per Foot Run. Weight of Round Iron and Steel Bars per Foot Run. Miscellaneous Data. Weight of Boiler (Formula). Weight of Water (Formula). Weight of Firebars. Weight of Coal. Miscellaneous Weights. Nuts for Boiler Tubes. Weight of Furnaces.

Steam Boilers: Their History and Development.

By **H. H. Powles, M.I.M.E., etc.**

Illustrated. Imperial 8vo. 24/- net.

Steam Pipes: Their Design and Construction.

By **W. H. Booth,** Author of "Liquid Fuel," etc.

Illustrated. Demy 8vo. 5/- net.

*Second
Edition.*

Steam Engines, Boilers, etc.—continued.

The New Steam Tables. Calculated from Professor Callendar's Researches.

By **Professor C. A. M. Smith, M.Sc.,** and **A. G. Warren, S.Sc.** 4/- net.

Experimental Researches on the Flow of Steam through Nozzles and Orifices,
to which is added a note on the Flow of Hot Water.

By **A. Rateau.** Crown 8vo. 4/6 net.

Superheat, Superheating, and their Control.

By **W. H. Booth, F.G.S., M.Am.Soc.C.E.**
Illustrated. Demy 8vo. 6/- net.

Fuel and Smoke

Oil Fuel Equipment for Locomotives.

By **Alfred H. Gibbings, A.M.Inst.C.E.**

Demy 8vo. Illustrations. Tables. 7/6 net.

A complete treatise on the application of oil and the fittings required for locomotive work.

An Introduction to the Study of Fuel.

A text-book for those entering the Engineering, Chemical and Technical Industries.

“OUTLINES OF INDUSTRIAL CHEMISTRY.”

By **F. J. Brislee, D.Sc.** *Illustrated.* Demy 8vo. 8/6 net.

General Chemical Principles. Weight and Volume of Air required for Combustion. Analysis of Fuel and Flue Gases. Calorimetry and Determination of the Heating Value of a Fuel. Measurement of High Temperatures. Pyrometry. Calculations of Combustion Temperatures. Natural Solid Fuels. Artificial Solid Fuels. Gaseous Fuel. The Manufacture of Producer Gas and Water Gas. Theory of the Producer Gas and Water Gas Reactions. Explosion and the Explosion Engine. Air Supply and Measurement of Draught. Furnace Efficiency and Fuel Economy. Heat Balances, Furnace and Boiler Tests. Liquid Fuels.

Liquid Fuel and its Apparatus. By **William H.**

Booth, F.G.S., M.Am.Soc.C.E., Author of “Liquid Fuel and its Combustion,” etc. *Demy 8vo. Price 8/6 net.*

PART I.—THEORY AND PRINCIPLES.

PART II.—PRACTICE.

PART III.—FURNACES.

Fuel and Smoke—continued.

Liquid Fuel and its Combustion.

By **W. H. Booth, F.G.S., M.Am.Soc.C.E.**, Author of
"Water Softening and Treatment," "Steam Pipes:
Their Design and Construction."

With about 120 Illustrations and Diagrams. Imp. 8vo. 24/- net.

Smoke Prevention and Fuel Economy.

By **W. H. Booth, F.G.S., M.Am.Soc.C.E.**, and **J. B. C. Kershaw, F.I.C.**

Illustrated. Third Edition, revised and enlarged. Demy 8vo. 6/- net.

Liquid and Gaseous Fuels, and the Part they play in Modern Power Production.

By **Professor Vivian B. Lewes, F.I.C., F.C.S.**, Late
Prof. of Chemistry, Royal Naval College, Greenwich.

With 54 Illustrations. Ex. Crown 8vo. 6/- net.

Fuel, Gas and Water Analysis for Steam Users.

By **J. B. C. Kershaw, F.I.C.** *Illustrated. Demy 8vo. 8/- net.*

Coal.

By **James Tonge, M.I.M.E., F.G.S., etc.** Lecturer on
Mining at Victoria University, Manchester. *With 46
Illustrations. Ex. Crown 8vo. 6/- net.*

Machinery, Power Plants, etc.

Theory and Practice of Mechanics.

By **S. E. Slocum, B.E., Ph.D.** *Demy 8vo. 442 + xlii pages.
Illustrated with diagrams, etc. 15/- net.*

Dynamometers.

By **Rev. Frederick John Jarvis-Smith, M.A., F.R.S.**
Edited and amplified by **Charles Vernon Boys, F.R.S.**

118 Illustrations. Demy 8vo. 14/- net.

CONTENTS: Introduction. Friction. Planimeters. Friction Brakes. Water Brakes. Air Brake. Magnetic Brake Dynamometer. End Thrust Brakes. Historical. Transmission Dynamometers. Torsion Power-Measuring Machines. Torsion Power-Measuring Machines by different Inventors. The Cradle Dynamometer. Dynamometric Tests of Motor-Car Engines. Model Ship Dynamometer. Dynamometers used in Aeronautics.

Machinery, Power Plants, etc.—continued.

A Handbook of Testing.

I.—Materials.

By **C. A. Smith, B.Sc., A.M.I.M.E., Assoc.M.I.E.E.**,
Professor of Engineering in the University of Hong Kong,
late of East London College, Author of "Lectures on
Suction Gas Plants," etc. *Demy 8vo. 6/- net.*

II.—Prime Movers. *In preparation.*

Mechanical Movements, Powers, Devices and Appliances. By **Gardner D. Hiscox, M.E.**, Author of "Gas, Gasoline, and Oil Engines," etc.

Over 400 pages. 1646 Illustrations and Descriptive Text. Demy 8vo. 8/6 net.

Mechanical Appliances.

SUPPLEMENTARY VOLUME TO MECHANICAL MOVEMENTS.

By **Gardner D. Hiscox, M.E.**

400 pages. About 1,000 Illustrations. Demy 8vo. 8/6 net.

Mechanical Technology.

By **G. F. Charnock, M.Inst.C.E., M.Inst.M.E.**

Demy 8vo. 650 pages. Illustrated. 7/6 net.

This work, designed chiefly for engineering students, deals in a comprehensive manner with the preparation and properties of the raw material, the production of castings by taking advantage of the property of fusibility, and the production of bars, plates, forgings, etc., by utilising the properties of malleability and ductility. It is perhaps the most complete manual on the subject in any language.

Mechanical Engineer.—"This is a book for which there is a decided want amongst engineering students and this excellent treatise leaves little for criticism but much for praise."

Mechanical World.—"The author is to be congratulated upon the production of a work which is certain to be gratefully appreciated by a large circle of young engineers, while those long past their 'prentice days will find much of interest and value in the book."

The Elements of Mechanics of Materials.

A TEXT-BOOK FOR STUDENTS IN ENGINEERING COURSES.

By **C. E. Houghton, A.B., M.M.E.** *Illustrated. Demy 8vo. 7/6 net.*

Forging of Iron and Steel.

**A TEXT-BOOK FOR THE USE OF STUDENTS IN COLLEGES,
SECONDARY SCHOOLS AND THE WORKSHOP.**

By **W. Allyn Richards.**

Demy 8vo. 337 Illustrations. Price 6/6 net.

CONTENTS.—Historic Use of Iron and Steel. Iron and Steel. Equipment. Fuel and Fires. Drawing Down and Upsetting. Bending and Twisting. Splitting, Punching and Riveting. The Uses of Blacksmiths' Tools. Welding. Electric, Autogenous and Thermit Welding. Brazing. Tool Steel. High Speed Tool Steel. Art Iron-work. Steam and Power Hammers. Calculations. Appendix. Index.

Machinery, Power Plants, etc.—continued.

Water Softening and Treatment : Condensing Plant, Feed Pumps and Heaters for Steam Users and Manufacturers. By **W. H. Booth, F.G.S., M.Am.Soc.C.E.** *Second Edition. With Tables and many Illustrations.* Demy 8vo. 7/6 net.

Cranes : Their Construction, Mechanical Equipment and Working.

By **Anton Böttcher.** Translated and supplemented with descriptions of English, American and Continental Practice, by **A. Tolhausen, C.E.** *Illustrated. Crown 4to. 42/- net.*

"This is by far the finest general work on cranes that has ever appeared. It is very voluminous and illustrated, and describes all existing types."—*The Engineer.*

Engineering Workshops, Machines and Processes.

By **F. Zur Nedden.** Translated by **John A. Davenport.** With an Introduction by **Sir A. B. W. Kennedy, LL.D., F.R.S.** *Illustrated. Demy 8vo. 6/- net.*

Dies : Their Construction and Use for the Modern Working of Sheet Metals. By **Joseph V. Woodworth.** 384 pages. *Illustrated. Demy 8vo. 12/6 net.*

Modern American Machine Tools.

By **C. H. Benjamin,** Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio, U.S.A., Member of American Society of Mechanical Engineers. *With 134 Illustrations. Demy 8vo. 18/- net.*

Precision Grinding.

A PRACTICAL BOOK ON THE USE OF GRINDING MACHINERY FOR MACHINE MEN. By **H. Darbyshire.** *Pages viii + 162. Illustrated. Demy 8vo. 6/- net.*

Shop Kinks :

Fourth Edition.

A BOOK FOR ENGINEERS AND MACHINISTS SHOWING SPECIAL WAYS OF DOING BETTER, CHEAP AND RAPID WORK.

By **Robert Grimshaw.** *With 222 Illustrations. Demy 8vo. 10/6 net.*

Cams, and the Principles of their Construction.

By **George Jepson,** Instructor in Mechanical Drawing in the Massachusetts Normal School. *Demy 8vo. 8/- net.*

Machinery, Power Plants, etc.—continued.

The Economic and Commercial Theory of Heat Power-Plants.

By **Robert H. Smith, A.M.Inst.C.E., M.I.M.E., M.I.E.E., etc.** Prof. Em. of Engineering and Mem. Ord. Meiji.

Numerous Diagrams. Royal 8vo. 24/- net.

Entropy : Or, Thermodynamics from an Engineer's Standpoint, and the Reversibility of Thermodynamics.

By **James Swinburne, M.Inst.C.E., M.I.E.E., etc.**

Illustrated with Diagrams. Crown 8vo. 4/6 net.

Compressed Air : Its Production, Uses and Applications. By **Gardner D. Hiscox, M.E.,** Author of "Mechanical Movements, Powers, Devices," etc.

*Fifth Edition,
Revised and
Enlarged.*

665 pages. 540 Illustrations and 44 Air Tables. Demy 8vo. 20/- net.

Natural Sources of Power.

By **Robert S. Ball, B.Sc., A.M.Inst.C.E.**

With 104 Diagrams and Illustrations. Ex. Crown 8vo. 6/- net.

Pumps

Centrifugal Pumps.

By **Louis C. Loewenstein, E.E., Ph.D., and Clarence P. Crissey, M.E.** 320 Illustrations. 18/- net.

CONTENTS.—Theory of Centrifugal Pumps. Consumption of Power and Efficiency. The Calculation of Impeller and Guide Vanes. Design of Important Pump Parts. Types of Centrifugal Pumps. Testing of Centrifugal Pumps.

Pumps and Pumping Engines : British Progress in.

By **Philip R. Björling,** Consulting Engineer, Author of "Pumps and Pump Motors;" "Pumps: their Construction and Management," etc.

Illustrated. Super-Royal 8vo. 6/- net.

Iron, Steel, and other Metals.

Iron, Steel, and other Metals

An Introduction to the Study of Physical Metallurgy. By **Walter Rosenhain, B.A., D.Sc., F.R.S.**, Superintendent, Metallurgy Department of the National Physical Laboratory. *With 32 Plates and 131 Illustrations in the Text. Demy 8vo. 10/6 net.*

The Basic Open-Hearth Steel Process.

By **Carl Dichmann**. Translated and Edited by **ALLEYNE REYNOLDS**. *Second Impression. Demy 8vo. Numerous Tables and Formulae. 10/6 net.*

Iron and Steel.

AN INTRODUCTORY TEXT-BOOK FOR ENGINEERS AND METALLURGISTS. "OUTLINES OF INDUSTRIAL CHEMISTRY." By **O. F. Hudson, M.Sc., A.R.C.S.**, Lecturer on Metallography, Birmingham University, with a Section on Corrosion by **Guy D. Bengough, M.A., D.Sc.**, Lecturer in Metallurgy, Liverpool University; Investigator to the Corrosion Committee of the Institute of Metals. *Demy 8vo. 6/- net.*

Forging of Iron and Steel. By **W. Allyn Richards**. *Price 6/6 net. (See p. 14.)*

Electro-Thermal Methods of Iron and Steel Construction.

By **J. B. C. Kershaw, F.I.C.** With an Introduction by **Dr. J. A. Fleming, F.R.S.** 239 + xxiii pages. 50 Tables and 92 Diagrams and Photographs. *Demy 8vo. 8/6 net.*

Malleable Cast Iron.

By **S. Jones Parsons, M.E.** *Illustrated. Demy 8vo. 8/- net.*
CONTENTS:—Melting. Moulding. Annealing. Cleaning and Straightening. Design. Patterns. Inspection and Testing. Supplementary Processes. Application.

General Foundry Practice : Being a Treatise on General Iron Founding, Job Loam Practice, Moulding, and Casting of Finer Metals, Practical Metallurgy in the Foundry, etc. By **William Roxburgh, M.R.S.A.** *With over 160 Figures and Illustrations. Extra Crown 8vo. 6/- net.*

Iron, Steel, and other Metals—continued.

Hardening, Tempering, Annealing and Forging of Steel. A TREATISE ON THE PRACTICAL TREATMENT AND WORKING OF HIGH AND LOW GRADE STEEL. By **Joseph V. Woodworth.**
288 pages. With 201 Illustrations. Demy 8vo. 10/- net.

Iron and Steel. By **J. H. Stansbie, B.Sc. (Lond.), F.I.C.**
With 86 Illustrations. Ex. Crown 8vo. 6/- net.

The Practical Mechanic's Handbook.

By **F. E. Smith.** *4/6 net. (See p. 47.)*

Welding and Cutting of Metals by the aid of Gases or Electricity.

By **Dr. L. A. Groth.** *Extra Crown 8vo. Illustrated. 6/- net.*

The Precious Metals : Comprising Gold, Silver and Platinum. By **Thomas K. Rose, D.Sc.,** of the Royal Mint. *Illustrated. Ex. Crown 8vo. 6/- net.*

Motor Cars and Engines

Text-Book of Motor Car Engineering.

By **A. Graham Clarke, M.I.A.E., A.M.I.M.E.**

Vol. I. Construction. *Illustrated. Demy 8vo. 8/6 net.*

CONTENTS:—The General Principles and Construction of the Petrol Engine. Details of Engine Construction. Petrol. Fuels other than Petrol. Carburettors and Carburation. Thermodynamics of the Petrol Engine. Horsepower. Mechanical (Thermal and Combustion Efficiencies). The Principles and Construction of Coil and Accumulator Ignition. Magneto Ignition. Engine Control Systems. Engine Cooling Systems. Crank Effort Diagrams. Clutches and Brakes. Change-Speed Gears. Transmission Gear. Steering Gears. Lubricants. Lubrication. Ball and Roller Bearings. Chassis Construction. General Principles of the Steam Car. Steam Engines and Condensers. Steam Generators and Pipe Diagrams. The Electric Car. Materials used in Motor Car Construction. Syllabus of City and Guilds of London Institute in Motor Car Engineering. Examination Papers. Physical Properties of Petrols. Mathematical Tables and Constants.

Vol. II. Design. *Illustrated. Demy 8vo. 7/6 net. In preparation.*

O'Gorman's Motor Pocket Book. By **Mervyn**

O'Gorman, M.I.M.E., etc. *Limf Leather Binding. 7/6 net.*

Motor Vehicles and Motor Boats.

See D.-S. Technical Dictionaries in Six Languages, p. 7.

Aeronautics

The Resistance of the Air and Aviation.

Experiments conducted at the Champ-de-Mars Laboratory, by **G. Eiffel**. *Second Edition. Revised and Enlarged.* Translated by **Jerome C. Hunsaker**, Assistant Naval Constructor United States Navy. *Over 130 Illustrations and Diagrams. Royal 4to. 42/- net.*

Dynamics of Mechanical Flight.

By **Sir George Greenhill** (late Professor of Mathematics in the R.M.A., Woolwich). *Demy 8vo. 8/6 net.*

Aircraft in Warfare : The Dawn of the Fourth Arm.

By **F. W. Lanchester**, **M.Inst.C.E.**, **M.Inst.A.E.**, Member Advisory Committee for Aeronautics. With Introductory Preface by **Maj.-Gen. Sir David Henderson, K.C.B.**, Director General of Military Aeronautics.

Illustrated. Medium 8vo. Price 12/6 net.

CONTENTS:—Aircraft as Constituting a New or Fourth "Arm." Primary and Secondary Functions of the Aeronautical Arm. Aeroplane *versus* Airship or Dirigible—Speed Limitations. Aeroplane and Dirigible in Armed Conflict. Means of Attack and Defence. Strategic and Tactical Uses of the Aeronautical Arm. The Strategic Scout and its Duties. Directing Artillery Fire by Aircraft. Aircraft as Vulnerable to Gun-fire. Armour and Altitude as Means of Defence. Low Altitude Flying. The Aeroplane in a Combatant Capacity—Armour Plate. The Machine Gun in the Service of the Aeronautical Arm. The Fighting Type of Aeroplane and its Future. As Affecting the Cavalry Arm. The Principle of Concentration. The Value of Numerical Strength. The *N-square* Law. The Principle of Concentration—*continued*. The *N-square* Law in its Application. Applications of the *N-square* Law in Naval Warfare. British Naval Tactics in 1805. Nelson's Tactical Scheme—The *N-square* Law at Trafalgar. Attack by Aeroplane on Aeroplane. The Fighting Machine as a Separate Type. The Question of Armament—Treaty Restrictions. Importance of Rapid Fire—Machine Guns Multiple Mounted. Rapidity of Fire and its Measure. Armour in its Relation to Armament. Importance of Upper "Gage"

Attack from Above. Armour and Shield Protection. Gun-fire Ballistics—The Energy Account. Expanding and Explosive Bullets. Theory of the Expanding Bullet. The Light-weight Shell. Miscellaneous Weapons and Means of Offence. The Bomb and the Hand Grenade. Bomb Dropping. Difficulties of Aiming. Rockets, Air-borne Torpedoes, etc. Supremacy of the Gun against Aircraft. Aircraft in the Service of the Navy—Naval Reconnaissance. Mother-ship or Floating Base. Armament of the Naval Aeroplane—the Employment of Bombs. Torpedo Attack by Air. Aeroplane and Submarine—Attack by Bomb. Aircraft in the Service of the Navy—*continued*. The Naval Air-scout. The Flying-Boat Type. The Double Float Type. The Ocean-going Floating Base or Pontoon-ship. The Command of

Aircraft in Warfare—continued.

the Air. Air Power as Affecting Combined Tactics. Defeat in the Air an Irreparable Disaster. Employment of Aircraft in Large Bodies. Air Tactics. An Independent Combatant Air Fleet and its Duties. Tactical Importance of Altitude. Formation Flying—Airmanship and Signalling. The "V" Formation and its Value. Aircraft Bases at High Altitude. The Command of the Air and its Limitations. Bel-ligerent Aircraft and the Rights and Obligations of Neutrals. Other International Questions Relating to Aircraft. Aircraft in Neutral Territory. Present Day Position—The Fourth Arm in Peace Time. The Flight Ground Question—Depreciation and Obsolescence. British Ascendancy in the Air. Causes which have Contributed to British Ascendancy. The Advisory Committee for Aeronautics. The Royal Aircraft Factory. The Maintenance of British Supremacy. Government *versus* Private Manufacture. Continuity of Policy—A Scheme of Control. A Board of Aeronautics Advocated. Retrospect—The Scope and Limitations of the Work. Supplementary Notes on the *N square* Law. Air Raids and the Value of Numbers. A Further Note on Aircraft and Submarine. The Strategic Employment of Aircraft on a Large Scale. Air Raids—Some Questions of National Defence. Power of Aggression as Affected by Radius of Action. The Extent of the Danger Zone. Air Raids as Affecting the Naval Outlook. Aeronautical and Naval Defence Indissolubly Associated. Future of Air Power: Essentially a National Question. Categorical Statement of Recommendations for Future Policy.

Aerial Flight. By **F. W. Lanchester.** *Illustrated.*

VOL. I.—AERODYNAMICS. *Demy 8vo. 21/- net.*

VOL. II.—AERODONETICS. *Demy 8vo. 21/- net.*

The Flying Machine from an Engineering Point of View, together with a Discussion concerning the Theory of Sustentation and Expenditure of Power in Flight.

By **F. W. Lanchester, M.Inst.C.E.**

Illustrated. Demy 8vo. 4/6 net.

Aeroplane Patents.

By **Robert M. Neilson, Wh.Ex., M.I.M.E., F.C.I.P.A.,**
Chartered Patent Agent, etc. *Demy 8vo. 4/6 net.*

Stability and Equilibrium of Floating Bodies.

By **Bernard C. Laws, B.Sc., A.R.C.Sc., A.M.Inst.C.E., M.I.N.A.**

250 + ix pages. 130 Illustrations. *Demy 8vo. 10/6 net. (See p. 21.)*

Aeroplanes.

See D.-S. Technical Dictionaries in Six Languages, Vol. X.,
p. 7.

Marine Engineering.

Marine Engineering

Marine Engine Design, including the Design of Turning and Reversing Engines.

By **Edward M. Bragg, S.B.** *Crown 8vo. 8/- net.*

Stability and Equilibrium of Floating Bodies.

By **Bernard C. Laws, B.Sc., A.R.C.Sc., A.M.Inst.C.E., M.I.N.A.**

250 + ix pages. 130 Illustrations. Demy 8vo. 10/6 net.

CONTENTS.—General Considerations. Ships. Amsler's Integrator. Submarines. Floating Docks. Aircraft. Caissons. Index.

Ship Form, Resistance, and Screw Propulsion.

By **G. S. Baker, M.Inst.Naval Architects.**

Medium 8vo. Illustrated. 12/6 net.

Treated from the practical point of view for the use of naval architects, engineers, and draughtsmen.

CONTENTS.—Nomenclature. Stream Line Motion. Skin Friction Resistance. Eddy-making. Waves and Wave-making. Ship Model Experiments. Dimensions and Form. Curve of Areas. Shape and Fineness of Ends, with Parallel Body. Position of Maximum Section, and Relative Length of Entrance and Run. Midship Section Area and Shape. Level Lines and Body Plan Sections. Racing and other High Speed Vessels. Appendages. Restricted Water Channels. Screw Propeller Nomenclature and Geometry. Theories of the Screw Propeller. The Elements of Propulsion. Screw Propellers in Open Water. Propeller Blades. Hull Efficiency, Wake and Thrust Deduction. Main Engines. Cavitation. Measured Mile Trials.

Cold Storage, Heating and Ventilating on Board Ship. By **Sydney F. Walker, R.N.**

Extra Crown 8vo. 8/- net.

The problems of cold storage and heating and ventilating are treated exactly as they are presented to a naval architect and marine engineer. Directions are given for detecting the causes of various troubles and remedying them, and, what is more important, explicit instructions are given for operating various types of plants, so as to avoid breakdowns. Comparatively little has hitherto been published on the subject.

The Elements of Graphic Statics and of General Graphic Methods.

By **W. L. Cathcart, M.Am.Soc.M.E., and J. Irvin Chaffee, A.M.** *159 Diagrams. 12/- net.*

This book is designed for students of marine and mechanical engineering and naval architecture. It reviews the principles of graphics and their application both to frame structures and to mechanism.

Marine Double-ended Boilers.

By **John Gray.** *Illustrated. Crown 8vo. 3/6 net. (See p. 11.)*

Marine Engineering—continued.

Handbook for the Care and Operation of
Naval Machinery. By **H. C. Dinger**. *Illustrated.*
Pocket Size, 7/6 net.

Turbines Applied to Marine Propulsion.

By **Stanley J. Reed, A.M.Inst.C.E.** *Crown 4to. Over 100*
Illustrations and Diagrams. 16/- net.

CONTENTS. — General Properties of Steam -- Two-Stage Rateau Turbine Nozzles. The General Design and Arrangement of Turbines. The Design and Construction of Parsons Turbine. The Design and Construction of Curtis Turbine. Combined or Mixed Turbines. Steam Thrust of Reaction Turbines. Superheated Steam. Cavitation. Relative Effect of High Vacua with Turbines and Reciprocating Engines. Utilisation of Auxiliary Engine Exhaust in the Turbines. Astern Turbines.

Turbines and Hydraulics

Ship Form, Resistance, and Screw Propulsion.

By **G. S. Baker, M.Inst.Naval Architects.**

Medium 8vo. Illustrated. 12/6 net. (See p. 21.)

Treated from the practical point of view for the use of naval architects, engineers, and draughtsmen.

Stability and Equilibrium of Floating Bodies.

By **Bernard C. Laws, B.Sc., A.R.C.Sc., A.M.Inst.C.E., M.I.N.A.**

250 + ix pages. 130 Illustrations. Demy 8vo. 10/6 net. (See p. 21.)

Hydraulics and its Applications: A Text-book

for Engineers and Students. By **A. H. Gibson,**

D.Sc., M.Inst.C.E. 2nd edition, revised and enlarged.

Demy 8vo. 15/- net.

"One of the most satisfactory text-books on Hydraulics extant." —

Mechanical World.

Hydraulics, Text-book of: Including an Outline

of the Theory of Turbines. By **L. M. Hoskins,**

Professor of Applied Mathematics in the Leland Stanford Junior University.

Numerous Tables. Illustrated. Demy 8vo. 10/6 net.

Water Hammer in Hydraulic Pipe Lines:

BEING A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE RISE OR FALL OF PRESSURE IN A PIPE LINE, CAUSED BY THE GRADUAL OR SUDDEN CLOSING OR OPENING OF A VALVE; WITH A CHAPTER ON THE SPEED REGULATION OF HYDRAULIC TURBINES.

By **A. H. Gibson, D.Sc., M.Inst.C.E.**

Crown 8vo. 5/- net.

Turbines and Hydraulics—continued.

Hydroelectric Developments and Engineering.

A PRACTICAL AND THEORETICAL TREATISE ON THE DEVELOPMENT, DESIGN, CONSTRUCTION, EQUIPMENT AND OPERATION OF HYDROELECTRIC TRANSMISSION PLANTS.

By **Frank Köester.**

21/- net.

Modern Turbine Practice and Water Power Plants, with Terms and Symbols used in Hydraulic Power Engineering.

By **John Wolf Thurso**, Civil and Hydraulic Engineer.

With many Diagrams and Illustrations. Royal 8vo. 16/- net.

Water Pipe and Sewage Discharge Diagrams.

By **T. C. Ekin, M.Inst.C.E., M.I.M.E.** (*See p. 31.*)

Mining

Electric Mine Signalling Installations. A Practical Treatise on the Fitting-up and Maintenance of Electrical Signalling Apparatus in Mines.

By **G. W. Lummis Paterson.**

Crown 8vo. 140 Illustrations. 4/6 net. (See p. 34.)

Mining and Mine Ventilation: A Practical Handbook on the Physics and Chemistry of Mining and Mine Ventilation.

By **Joseph J. Walsh.**

Extra Crown 8vo. Price 8/6 net.

CONTENTS: Matter. Motion, Velocity and Force. Gravitation. Liquids and Liquid Pressure. Heat. Gases. The Barometer. Specific Heat. Mine Ventilation. Formulas. Mine Fires.

Application of Electric Power to Mines and Heavy Industries.

By **W. H. Patchell, M.Inst.C.E., M.I.M.E., M.Am.I.E.E.**

Demy 8vo. 10/6 net.

CONTENTS:—Electricity in Mines. Cables. Coal Cutters and Underground Details. Haulage Gears. Rating of Haulages. Winding Engines. Types of Electric Winders. Ventilation and Air Compressing. Pumping. Rolling Mills. Machine Tools and Cranes. Electric Welding and Furnaces.

Railway Engineering.

Railway Engineering

Railway Maintenance Engineering.

With Notes on Construction. By **William H. Sellew, A.S.M.E.**, Author of "Steel Rails, their History, Properties, Strength and Manufacture," Member of the American Railway Engineering Association.

CONTENTS—Engineering. Land. Grading. Bridges, Trestles and Culverts. Ties. Rails. Other Track Material. Ballast. Maintaining Track and Right of Way. Station and Roadway Buildings. Water Stations. Fuel Stations. Shops and Engine Houses. Icing Stations. Signals and Interlockers.

Oil Fuel Equipment for Locomotives.

By **Alfred H. Gibbings, A.M.Inst.C.E.**

Demy 8vo. Illustrations. Tables. 7/6 net.

A complete treatise on the application of oil and the fittings required for locomotive work.

Steel Rails. Their History, Properties, Strength and Manufacture. With Notes on the Principles of Rolling Stock and Track Design. By William H. Sellew.

361 Illustrations, 33 Folding Plates, 576 pages, 52/- net.

CONTENTS.—Development of the Present Section. Pressure of the Wheel on the Rail. Supports of the Rail. Stresses in the Rail. Strength of the Rail. Influence of Detail of Manufacture. Rail Specifications. Appendix.

Solution of Railroad Problems by the Slide Rule. By E. R. Cary, M.Am.S.C.E.

145 pages. 43 Diagrams. 4/6 net.

The Practical Railway Spiral: With short working formulas and full tables of deflection angles. Complete notes of illustrative examples.

By **L. C. Jordan, B.S.**

164 pages. Illustrated. 6/- net.

Single-Phase Electric Railways. By E. Austin.

Over 290 pages. 346 Illustrations. 21/- net. (See p. 34.)

Reinforced Concrete Railway Structures.

By **J. D. W. Ball, A.M.Inst.C.E.** *Demy 8vo. 8/- net.*

"Glasgow Text-Books of Civil Engineering"

CONTENTS.—Preliminary Considerations. Shear Stress. Floors and Buildings. Foundations. Retaining Walls. Bridges. Arched Bridges. Sleepers, Fence Posts, etc. Summary of Notation.

Railway Engineering—continued.

The Design of Simple Steel Bridges.

By **P. O. G. Usborne, late R.E.** 12/6 net.

CONTENTS.—Definitions. Bending Moments. Moments of Flexure. Moments of Resistance. Shear Deflection. Solid Beams and Examples. Struts and Ties. Rivets and Joints. Rolling Loads. Bending Moments, Shear Stresses. Loads. Plate Girders. Bridge Floors. Railways, Roads. Principles of Bridge Design. Plate Girders. Parallel Braced Girders. Braced Girders (2). Shop Practice and General Details.

Reinforced Concrete Bridges.

By **Frederick Rings, M.S.A., M.C.I.** (See p. 26.)

Railway Signal Engineering (Mechanical).

By **Leonard P. Lewis**, of the Caledonian Railway, Glasgow.
"Glasgow Text-Books of Civil Engineering," *Illustrated. Demy 8vo. 8/- net.*

CONTENTS.—Introduction. Board of Trade Rules. Classes and Uses of Signals. Constructional Details of Signals. Point Connections. Interlocking Apparatus. Signal Box Arrangements. Miscellaneous Apparatus. Signalling Schemes. Interlocking Tables, Diagrams, etc. Methods of Working Trains. Appendix.

Railway Terms. Spanish-English, English-Spanish, Dictionary of.

By **André Garcia.** 12/6 net.

The Railway Locomotive: What it is, and Why it is What it is.

By **Vaughan Pendred, M.I.M.E., M.I. & S.Inst.**
Illustrated. Ex. Crown 8vo. 6/- net.

Railway Shop Up-to-Date.

A reference book of American Railway Shop Practice.
Compiled by the **Editorial Staff of the "Railway Master Mechanic."** 4to. 12/6 net.

The Field Engineer.

18th Edition, Revised and Enlarged.

By **William Findlay Shunk.** Foolscap 8vo. Leather. 10/6 net.

Reinforced Concrete and Cement

A Treatise on Cement Specifications, including the General Use, Purchase, Storage, Inspection and Test Requirements of Portland, Natural, Puzzolan (slag), and Silica (sand) Cement, and Methods of Testing and Analysis of Portland Cement.

By **Jerome Cochran, B.S., C.E., M.C.E.** Author of
"Inspection of Concrete Construction," etc.

Demy 8vo. 100 pages. 6/- net.

Reinforced Concrete and Cement—continued.

Reinforced Concrete Railway Structures.

By **J. D. W. Ball, A.M.Inst.C.E.** (See p. 24.)

Reinforced Concrete Bridges.

By **Frederick Rings, M.S.A., M.C.I.,** Architect and Consulting Engineer.

Over 300 Illustrations and Diagrams. Imp. 8vo. 21/- net.

A Manual of Cement Testing. For the use of

Engineers and Chemists in Colleges and in the Field.

By **W. A. Richards, B.S. in M.E.,** and **H. B. North, D.Sc.**

137 + x pages. 54 Diagrams. Demy 8vo. 6/- net.

Manual of Reinforced Concrete and Concrete

Block Construction. *Third Edition, Rewritten and*

Enlarged, with the addition of much useful information and many new Tables and Diagrams.

By **Charles F. Marsh, M.Inst.C.E., M.Am.Soc.E., M.I.M.E.,** and **William Dunn, F.R.I.B.A.**

Pocket size, limp Morocco, 290 pages, with 52 Tables of Data and 112 Diagrams. Price 10/6 net.

A Concise Treatise on Reinforced Concrete :

A Companion to "The Reinforced Concrete Manual."

By **Charles F. Marsh, M.Inst.C.E., M.Am.Soc.E.,**

M.I.M.E. *Demy 8vo. Illustrated. 7/6 net.*

Properties and Design of Reinforced Concrete.

INSTRUCTIONS, AUTHORISED METHODS OF CALCULATION, EXPERIMENTAL RESULTS AND REPORTS BY THE FRENCH GOVERNMENT COMMISSIONS ON REINFORCED CONCRETE.

By **Nathaniel Martin, A.G.T.C., B.Sc., A.M.Inst.C.E.,**

Former Lecturer on Reinforced Concrete in the Royal West of Scotland Technical College. *8/- net.*

Reinforced Concrete Compression Member

Diagram : A Diagram giving the loading size and reinforcements for compression members according to the data and methods of Calculation recommended in the Second Report of the Joint Committee on Reinforced Concrete and adopted in the Draft Regulations of the London County Council.

By **Charles F. Marsh, M.Inst.C.E., M.Am.Soc.E., M.I.M.E.**

In Cloth Covers. Mounted on Linen, 5/- net. Unmounted, 3/6 net.

Cement, Concrete, and Bricks. By **A. B. Searle.**

Demy 8vo. Illustrated. 8/6 net. (See p. 46.)

Reinforced Concrete and Cement—continued.

Cement and Concrete.

*Second Edition, Revised
and Enlarged.*

By **Louis Carlton Sabin, B.S.**, Assistant Engineer,
Engineer Department, U.S. Army; Member of the American
Society of Civil Engineers. *Large Demy 8vo. 21/- net.*

Civil Engineering, Building Construction, etc.

Civil Engineers' Pocket Book. A Reference-Book
for Engineers, Contractors and Students, containing
Rules, Data Methods, Formulæ and Tables.

By **A. I. Frye, S.B., M.Am.S.C.E.** *21/- net.*

A Treatise on Cement Specifications.

By **Jerome Cochran, B.S., C.E., M.C.E.** (*See p. 25.*)

**The Principles of the Application of Power
to Road Transport.**

By **H. E. Wimperis, A.M.Inst.C.E., A.M.I.E.E.** *Illustrated.*
Crown 8vo. 4/6 net.

The Design of Simple Steel Bridges.

By **P. O. G. Usborne, late R.E.** (*See p. 25.*)

The Elements of Structural Design. *Medium 8vo.*

By **Horace R. Thayer.**

VOL. I.—ELEMENTS. *6/- net.*

VOL. II. DESIGN. *500 pages, 16/- net.*

Discusses the design of simple structures such as beams, girders,
viaducts, trusses, buildings, stand pipes, and elevated tanks.

Reinforced Concrete Railway Structures.

By **J. D. W. Ball, A.M.Inst.C.E.** (*See p. 24.*)

**The Elastic Arch : With Special Reference to the
Reinforced Concrete Arch.**

By **Burton R. Leffler**, Engineer of Bridges, Lake Shore
and Michigan Southern Railway. *Diagrams and Tables. Crown
8vo. 4/- net.*

Practical Design of Steel-Framed Sheds.

By **Albert S. Spencer.**

Illustrated. Royal 8vo. 10/6 net.

CONTENTS:—The Resistance of Steel-Framed Sheds to Wind Forces. The Standardisation of Shed Members and Foundations. Sheeted Sheds. Standard Sections for Sheds with Open Sides and Gables. Sheeted Roofs. Standardising of Shed Members and Foundations for Sheds having Slated Roofs and Brick-panelled Walls. Standard Sections for Sheds with Open Sides and Gables. Slated Roofs. Standard Stresses and Sections for Roof Principals. External Coverings. Gutters, Pipes, Ventilation, Doors, Windows, and Skylights.

A Study of the Circular-Arc Bow-Girder.

By **A. H. Gibson, D.Sc., A.M.Inst.C.E., M.I.Mech.E.,**
and **E. G. Ritchie, B.Sc.**

Illustrated. 8/6 net.

Masonry Applied to Civil Engineering.

By **F. Noel Taylor.**

Illustrated. Demy 8vo. 6/- net.

CONTENTS:—Stones used in Constructional Work. General Remarks upon Masonry. Retaining Walls and Earth Pressures. Dock, River, Canal, and Sea Walls. Masonry Dams. Masonry Bridges and Arches. Masonry Towers, etc. Monolithic and Block Concrete Construction. Shoring and Underpinning. Index.

Foundations and Machinery Fixing.

By **Francis H. Davies, A.M.I.E.E.** 2/- net.

CONTENTS:—The Functions of Foundations, Nature of Soils and Piling. Trial Bores. Design of Foundations. Design. The Proportions of Foundations for Engines, Turbines and Dynamo. Electric Machinery. Materials for Foundations. Holding Down Bolts and Anchor Plates. Excavation. Construction of Foundations. Vibration: Its Causes and Effects. Vibration. Methods of Isolating Machinery. The Fixing of Electric Motors.

Graphical Determination of Earth Slopes, Retaining Walls and Dams.

By **Charles Prelini, C.E.,** Author of "Tunnelling."

Demy 8vo. 8/- net.

Tunnel Shields and the Use of Compressed Air in Subaqueous Works.

Second Edition.

By **William Charles Copperthwaite, M.Inst.C.E.**

With 260 Illustrations and Diagrams. Crown 4to. 31/6 net.

Rainfall, Reservoirs and Water Supply.

By **Sir Alexander Binnie, M.Inst.C.E., etc.** 8/6 net. (*See*
p. 30.)

Civil Engineering, etc.—continued.

Modern Tunnel Practice.

By **David McNeely Stauffer, M.Am.S.C.E., M.Inst.C.E.**
With 138 Illustrations. Demy 8vo. 21/- net.

Timber.

By **J. E. Baterden, Assoc.M.Inst.C.E.**
Illustrated. Ex. Crown 8vo. 6/- net.

Pricing of Quantities.

SHOWING A PRACTICAL SYSTEM OF PREPARING AN ESTIMATE FROM BILLS OF QUANTITIES. By **George Stephenson**,
Author of "Repairs," "Quantities," etc. *Ex. Cr. 8vo. 3/6 net.*

Building in London. By **Horace Cubitt, A.R.I.B.A., etc.**

A Treatise on the Law and Practice affecting the Erection and Maintenance of Buildings in the Metropolis, with Special Chapters dealing respectively with the Cost of Building Work in and around London by **H. J. LEANING, F.S.I.**, and the Valuation and Management of London Property by **SYDNEY A. SMITH, F.S.I.**: also the Statutes, Bye-laws and Regulations applying in London; cross-references throughout.
Illustrated, with Diagrams. Royal 8vo. 31/6 net.

Theory and Practice of Designing.

With numerous Illustrations.

By **Henry Adams, M.Inst.C.E., M.I.M.E.** 6/- net.

"This is one of the best elementary books on the design of girders, roofs, and similar structures, with which we are acquainted. The subject is one with which the author is thoroughly *au fait*. . . The work throughout is simple and practical; only the simplest mathematics are used, and this is amplified by numerous worked out examples. The arrangement is progressive and permits those with comparatively little knowledge of the subject to follow it by easy stages. . . We recommend it heartily, alike as a text-book or a handy work of reference."—*Mechanical Engineer*.

Surveying, etc.

Adjustment of Observations by the

*Second
Edition.*

Method of Least Squares: With Application to Geodetic Work.

By **Professor Thomas Wallace Wright, M.A., C.E.**,
and **John Fillmore Hayford, C.E.**, Chief of the Computing Staff U.S. Coast and Geodetic Survey.

With Tables. Demy 8vo. 12/6 net.

Surveying and Field Work.

By **J. Williamson, A.M.Inst.C.E.**

Demy 8vo. 7/6 net.

CONTENTS.—Surveying. Fundamental Principles. Chain Surveying. Instruments—Chain Surveying. Field Operations—Chain Surveying. Running a Survey Line—Chain Surveying. Arrangement of Survey.

Surveying, etc.—continued.

Surveying and Field Work—*continued.*

Lines—Chain Surveying. Errors—Chain Surveying. Special Problems. Plotting the Plan. Compass and Sextant Surveying. The Theodolite. Traverse Surveying with the Theodolite. Plotting a Traverse Survey by Angle and Distance. Plotting Traverse Survey by Co-ordinate or Latitude and Departure Method. Triangulation. Some Survey, Traverse, and Triangulation Problems. Levelling. Errors in Levelling. Sections, Contours, &c. Setting out Curves, &c. Calculation of Areas. Calculation of Earthwork Quantities. Adjustment of Instruments. Appendix. Geometric and Trigonometric Formulæ. Index.

Practical Surveying: For Surveyors' Assistants and Students. By **Ernest McCullough, C.E.**, Member of the American Society of Civil Engineers.

Extra Cr. 8vo. 229 Illustrations. Price 8/6 net.

CONTENTS.—Introductory. Chain Surveying. Levelling. Compass Surveying. Trigonometry. Transit Surveying. Surveying Law and Practice. Engineering Surveying. Appendix. The Essentials of Algebra.

Municipal Engineering

Water Purification and Sewage Disposal.

By **Dr. J. Tillmans**, Director of the Chemical Department of the Municipal Institute of Hygiene, Frankfort-on-Maine.

Translated by **Hugh S. Taylor, M.Sc.** *Illustrated. 144 1 xv pages. Demy 8vo. 7/6 net.*

Sewage Disposal Works: Design, Construction and Maintenance.

Being a Practical Guide to Modern Methods of Sewage Purification.

By **Hugh P. Raikes, M.Inst.C.E.** *Demy 8vo. 16/- net.*

Rainfall, Reservoirs and Water Supply.

By **Sir Alexander Binnie.** *8/6 net. (THE CHADWICK LIBRARY)*

CONTENTS.—Rainfall. Average. Fluctuations. Probable Average Flow from the Ground. Intensity of Floods. Evaporation. Quantity and Rate per Head. Quality, Hardness, etc. Impurities. Filtration. Sources of Supply. Gravitation *versus* Pumping. Rivers and Pumping Works. Drainage Areas. Deductions from Rainfall. Compensation. Capacity of Reservoirs. Sites of Reservoirs. Puddle Trenches. Concrete Trenches. Base of Embankment. Reservoir Embankments. Puddle Wall. Formation of Embankment. Masonry Dams. Reservoir Outlets. Pipes through Embankment. Culvert under Embankment. Flow through Culverts. Valve Pit. Central Stopping. Tunnel Outlets. Syphon Outlets. Flood or Bye-channel. Waste Watercourse and Waste Weir. Aqueducts. Conduits. Pipes. Service Reservoir. Distribution. Valves. Meters. House Fittings. Index.

Refuse Disposal and Power Production.

By **W. F. Goodrich.** *Illustrated. Demy 8vo. 16/- net.*

Small Dust Destructors for Institutional and Trade Refuse.

By **W. F. Goodrich.** *Illustrated. Demy 8vo. 4/- net.*

British Progress in Municipal Engineering.

By **William H. Maxwell, A.M.Inst.C.E.**

Illustrated. Super-Royal 8vo. 6/- net.

Water Pipe and Sewage Discharge Diagrams.

By **T. C. Ekin, M.Inst.C.E., M.I.Mech.E.** *Folio. 6/- net.*

These diagrams and tables with accompanying descriptive letterpress and examples are based on Kutter's formula with a coefficient of roughness of 0.013 and give the discharges in cubic feet per minute of every inch diameter of pipe from 3 to 48 inches when running full on inclinations from 1 to 15 per 1000.

Modern Sanitary Engineering. Part I. House Drainage.

"Glasgow Text-Books of Civil Engineering."

By **Gilbert Thomson, M.A., M.Inst.C.E.** *Demy 8vo. 6/- net.*

Introductory. The Site and Surroundings of the House. The General Principles of Drainage Design. Materials for Drains. The Size of Drains. The Gradient of Drains. Drain Flushing Traps: Their Principle and Efficacy. Traps: Their Number and Position. "Disconnections." Intercepting Traps and Chambers. Inspection Openings and Manholes. Soil, Waste, and Connecting Pipes. Water Closets. Flushing Cisterns and Pipes. Urinals. Baths. Lavatory Basins. Sinks, Tubs, etc. Trap Ventilation. Designing a System of Drainage. Buildings of Special Class. Test and Testing. Sanitary Inspections. Sewage Disposal for Isolated Houses. Index.

The Encyclopaedia of Municipal and Sanitary Engineering.

Edited by **W. H. Maxwell, A.M.Inst.C.E.** (See p. 5.)

Irrigation and Water Supply Water Purification and Sewage Disposal.

By **Dr. J. Tillmans.** (See p. 30.)

Rainfall, Reservoirs and Water Supply.

By **Sir Alexander Binnie, M.Inst.C.E.** *Demy 8vo. Illustrated. 8/6 net.* (See p. 30.)

Irrigation and Water Supply—continued.

Irrigation : Its Principles and Practice as a Branch of Engineering.

By **Sir Hanbury Brown, K.C.M.G., M.Inst.C.E.**

Second Edition. Illustrated. Demy 8vo. 16/- net.

CONTENTS:—Irrigation and its Effects. Basin Irrigation. Perennial Irrigation and Water "Duty." Sources of Supply. Dams and Reservoirs. Means of Drawing on the Supply. Methods of Construction. Means of Distribution. Masonry Works on Irrigation Canals. Methods of Distribution of Water. Assessment of Rates and Administration. Flood Banks and River Training. Agricultural Operations and Reclamation Works. Navigation. Appendices I, II, III. Index.

Irrigation Works.

THE "VERNON HARCOURT" LECTURES OF 1910.

By **Sir Hanbury Brown, K.C.M.G., M.Inst.C.E.**

Demy 8vo, stiff paper cover. 1/- net.

The Practical Design of Irrigation Works.

By **W. G. Bligh, M.Inst.C.E. Second Edition.**

Enlarged and rewritten, with over 240 Illustrations, Diagrams and Tables. Imp. 8vo. 26/- net.

CONTENTS:—Retaining Walls. Dams (Section). Weirs (Section). Piers, Arches, Abutments and Floors. Hydraulic Formulas. Canal Head Works—Part I. Submerged Diversion Weirs; Part II. Under-sluices; Part III. Canal Head Regulators. Canal Falls. Canal Regulation Bridges and Escape Heads. Canal Cross-Drainage Works. Design of Channels. Reservoirs and Tanks. Screw Gear for Tank Sluices and Roller Gates. Appendix.

Notes on Irrigation Works.

By **N. F. Mackenzie, Hon. M.A., Oxon.; M.Inst.C.E.;**
lately Under-Secretary for Irrigation to the Government of India. *Demy 8vo. 7/6 net.*

Telegraphy and Telephony

Telegraph Engineering.

By **E. Hausmann, E.E., Sc.D.**

Demy 8vo. 192 Illustrations. 12/6 net.

For practising telegraph engineers and engineering students,
It presents in a logical manner the subject of modern land and submarine telegraphy from an engineering viewpoint.

The Propagation of Electric Currents in Telephone and Telegraph Conductors.

BY **J. A. Fleming, M.A., D.Sc., F.R.S.**, Pender Professor of Electrical Engineering in the University of London.

Preface. Mathematical Introduction. The Propagation of Electromagnetic Waves Along Wires. The Propagation of Simple Periodic Electric Currents in Telephone Cables. Telephony and Telegraphic Cables. The Propagation of Currents in Submarine Cables. The Transmission of High-Frequency and Very Low-Frequency Currents Along Wires. Electrical Measurements and Determination of the Constants of Cables. Cable Calculations and Comparison of Theory with Experiment. Loaded Cables in Practice.

Second Edition. Demy 8vo. 8/6 net.

Toll Telephone Practice.

BY **J. B. Theiss, B.S., LL.B.**, and **Guy A. Joy, B.E.**
WITH AN INTRODUCTORY CHAPTER. BY **Frank F. Fowle, S.B.** *Illustrated. 14/- net.*

CONTENTS.—Rural Telephone Equipment. Toll Cut-in Stations. Toll Positions at a Local Switchboard. Toll Switching Systems. Small Toll Switchboards. Multiple-Drop Toll Switchboards. Multiple-Lamp Toll Switchboards. Toll Connections to Local Automatic Systems. Supervisory Equipment and Toll Chief Operator's Desk. Toll Wire Chief's Desk. Simplex Systems. Composite Systems. Phantom Lines. Test and Morse Boards. Small Test Panels. Line Construction. Electrical Reactions in Telephone Lines. Cross Talk and Inductive Disturbances. Methods of Testing. Toll Line Maintenance. The Telephone Repeater.

Radio-Telegraphy. BY **C. C. F. Monckton, M.I.E.E.**
With 173 Diagrams and Illustrations. Ex. Crown 8vo. 6/- net.

Maxwell's Theory and Wireless Telegraphy.

PART I.—Maxwell's Theory and Hertzian Oscillations, by **H. Poincaré**; translated by **F. K. Vreeland**. PART II.—The Principles of Wireless Telegraphy, by **F. K. Vreeland**.

Diagrams. Demy 8vo. 10/6 net.

The Telegraphic Transmission of Photographs. BY **T. Thorne Baker, F.C.S., F.R.P.S., A.I.E.E.**

With 66 Illustrations and Diagrams. Crown 8vo. 2/6 net.

Public Ownership of Telephones.

BY **A. N. Holcombe.** *8/6 net.*

"We commend this book to the notice of all interested in the study of telephone development and administration."—*Electricity.*

Electrical Engineering.

Electrical Engineering

Single-Phase Electric Railways.

By **E. Austin.**

Over 290 pages. 346 Illustrations. 21/- net.

CONTENTS:—The Single-Phase System. The London, Brighton and South Coast Railway. The Midland Railway. The Midi Railway. The Blankenese-Hamburg-Ohlsdorf Railway. The Dessau-Bitterfeld Railway. The Murnau-Oberammergau Railway. The Mittenwald Railway. The St Polten-Mariazell Railway. The Martigny-Orsières Railway. The Valle-Maggia Railway. The Rhätian Railway. The Lötschberg-Simplon Railway. The Rotterdam-Scheveningen Railway. The Thamshavn-Lokken Railway. The Rjukan Railway. The Swedish State Railways. The Parma Single-Phase Tramways. The New York, New Haven, and Hartford Railway. The New York, Westchester, and Boston Railway. The Spokane and Inland Empire Railway. The Rock Island and Southern Railway. The Hoosac Tunnel Railway. The St. Clair Tunnel Railway.

Overhead Transmission Lines and Distributing Circuits : Their Design and Construction.

By **F. Kapper.** Translated by **P. R. Friedlaender, M.I.E.E.**

Crown 4to. Illustrated. 16/- net.

A very thorough and much needed treatise dealing exhaustively with this important subject.

CONTENTS:—Conductor Materials. Sag and Tension of the Line. Design of the Supporting Structures. Stability of Poles and Masts. The Forces on the Foundation Piece. Fixing the Poles in the Ground. Concrete and Cement Foundation Work. Pole Construction. Overhead Line Insulators. Attachment of the Insulators to their Pins. Attachment of the Wire to the Insulators. Joints and Branch Connections on the Wire. Arrangement of the Wires. Earthing. Crossing over Postal Wires, Railways, and Roads. Erection of Poles and Masts. Erecting the Wire. Rules and Hints for the Design and Erection of Overhead Lines. Instruments for Surveying and Laying out the Route of a Line. Surveying the Route of a Transmission Line. The Most Economical Length of Span. Comparison of the various Supporting Structures with Reference to the Minimum Annual Charges. Local Overhead Distributing Systems. Agreements with Contractors. Tools and Appliances. Regulations dealing with the Erection and Operation of Overhead Lines.

Electric Mine Signalling Installations. A Practical Treatise on the Fitting-up and Maintenance of Electrical Signalling Apparatus in Mines.

By **G. W. Lummis Paterson.**

Cr. 8vo. 140 Illustrations. 4/6 net.

CONTENTS.—Ringing Keys and Tappers. Electric Mining Bells, Signal Alarms and Relays. Electric Mining Indicators or Annunciators. Electric Generators for Mine Signal Installations. Primary Batteries for Signal Installations. Electric Mining Shaft Signals. Electric Shaft Signal Wiring. Electric Engine Plane Signals. Electric Engine Plane Signal Wiring. Appendix.

Electrical Engineering—continued.

Application of Electric Power to Mines and Heavy Industries.

By **W. H. Patchell**, M.Inst.C.E., M.I.M.E., M.Am.I.E.E.
Demy 8vo. 10/6 net. (See p. 23.)

Transmission Line Formulas: For Electrical Engineers and Engineering Students.

By **H. B. Dwight**, A.M.Am.I.E.E.
143 pages. 28 Diagrams. 8/6 net.

Electric Cooking, Heating, Cleaning, Etc. Being a Manual of Electricity in the Service of the Home.

By "**Housewife**" (**Maud Lancaster**). Edited by **E. W. Lancaster**, A.M.Inst.C.E., M.Inst.E.E.
Illustrated. 338 + x pages. Demy 8vo. 3/6 net.

Electric Mechanism. PART I.

SINGLE-PHASE COMMUTATOR MOTORS.

By **F. Creedy**, A.C.G.I., A.M.I.E.E., Assoc.Am.I.E.E.
Demy 8vo. 7/6 net.

Switches and Switchgear.

By **R. Edler**. Translated, Edited and Adapted to English and American Practice by **Ph. Laubach**, A.M.I.E.E.

Illustrated. Demy 8vo. 15/- net.

CONTENTS.—General Remarks on the Design of Switchgear. Connecting Leads—Cable Sockets—Connections—Copper Bars—Contact Blocks—Bolts. Contact Springs and Brushes—Carbon Contacts—Devices to Eliminate Sparking at the Main Contacts. Switches and Change-over Switches for Low Pressure and Medium Pressure. High Pressure Switches. Fuses. Self-Acting Switches (Automatic Switches). Starting and Regulating Resistances—Controllers.

High and Low Tension Switchgear Design.

By **A. G. Collis**, A.M.I.E.E.

Demy 8vo. 218 +xiv pages. 94 Illustrations. 10/6 net.

Solenoids, Electromagnets and Electromagnetic Windings.

By **Charles Underhill**, A.M.A.I.E.E.

346 pages. Cloth. 218 Illustrations. Demy 8vo. 8/- net.

Electrical Engineer's Pocket Book. "FOSTER."

A HANDBOOK OF USEFUL DATA FOR ELECTRICIANS AND ELECTRICAL ENGINEERS.

By **Horatio A. Foster, M.A.I.E.E., M.A.S.M.E.**

With the Collaboration of Eminent Specialists.

Fifth Edition, completely Revised and Enlarged. Pocket size. Leather bound. With thumb index. Over 1,600 pages. Illustrated. 21/- net.

The Propagation of Electric Currents in Telephone and Telegraph Conductors.

By **J. A. Fleming, M.A., D.Sc., F.R.S.** (See p. 33.)

The Electrical Conductivity and Ionization Constants of Organic Compounds.

By **Heyward Scudder, B.A., B.S., M.D.**

Royal 8vo. 568 pages. 12/- net.

The Design of Static Transformers.

By **H. M. Hobart, B.Sc., M.Inst.C.E.**

Demy 8vo. Over 100 Figures and Illustrations. 6/- net.

Electricity: A Text-book of Applied Electricity. By **H. M. Hobart, B.Sc., M.Inst.C.E.**

With 43 Tables and 115 Illustrations. Demy 8vo. 208 + xix pages. 6/- net.

Heavy Electrical Engineering.

By **H. M. Hobart, B.Sc., M.Inst.C.E.**

Illustrated with Diagrams, etc. Demy 8vo. 16/- net.

Electric Railway Engineering.

By **H. F. Parshall, M.Inst.C.E., etc., and H. M. Hobart, B.Sc., M.Inst.C.E.** 476 pages and nearly 600 Diagrams and Tables.

Imp. 8vo. 42/- net.

American Electric Central Station Distribution Systems.

By **Harry Barnes Gear, A.M.A.I.E.E., and Paul Francis Williams, A.M.A.I.E.E.**

Illustrated. Demy 8vo. 12/- net.

Electrical Engineering—continued.

Electric Railways: Theoretically and Practically Treated.

Illustrated with Numerous Diagrams. Demy 8vo. Price 10/6 net each volume. Sold separately.

By **Sidney W. Ashe, B.S.**, Department of Electrical Engineering, Polytechnic Institute of Brooklyn, and **J. D. Keiley**, Assistant Electrical Engineer, N.Y.C. and H.R.R.R.

VOL. I.—ROLLING STOCK.

VOL. II.—ENGINEERING PRELIMINARIES AND DIRECT-CURRENT SUB-STATIONS.

Electric Lamps.

By **Maurice Solomon, A.M.I.E.E.** 6/- net.

Hydroelectric Developments and Engineering.

A PRACTICAL AND THEORETICAL TREATISE ON THE DEVELOPMENT, DESIGN, CONSTRUCTION, EQUIPMENT AND OPERATION OF HYDROELECTRIC TRANSMISSION PLANTS.

By **Frank Köester**, Author of "Steam - Electric Power Plants." 479 pages. 500 Illustrations. 45 Tables. Imperial 8vo. 21/- net.

Steam-Electric Power Plants.

A PRACTICAL TREATISE ON THE DESIGN OF CENTRAL LIGHT AND POWER STATIONS AND THEIR ECONOMICAL CONSTRUCTION AND OPERATION.

By **Frank Köester.** 474 pages. Illustrated. Cr. 4to. 21/- net.

Electric Power and Traction.

By **F. H. Davies, A.M.I.E.E.**

With 66 Illustrations. Ex. Crown 8vo. 6/- net.

Industrial Electrical Measuring Instruments.

By **Kenelm Edgcumbe, A.M.Inst.C.E., M.I.E.E.**

240 pages. 126 Illustrations. Demy 8vo. 8/- net.

Laboratory and Factory Tests in Electrical Engineering.

By **George F. Sever and Fitzhugh Townsend.**

Second Edition. Thoroughly revised. 282 pages. Demy 8vo. 10/6 net.

The Theory of Electric Cables and Networks.

By **Alexander Russell, M.A., D.Sc.**

Illustrated. Demy 8vo. 8/- net.

Testing Electrical Machinery.

By **J. H. Morecroft and F. W. Hehre.** 6/- net.

Electrical Engineering—continued

Continuous Current Engineering.

By **Alfred Hay, D.Sc., M.I.E.E.** *Second Edition.*
About 330 pages. Illustrated. Demy 8vo. 5/- net.

A new and revised edition of this popular text-book.

Direct and Alternating Current Testing.

By **Frederick Bedell, Ph.D.**, Professor of Applied Electricity,
Cornell University. Assisted by **Clarence A. Pierce, Ph.D.**
Enlarged and Revised Edition. Demy 8vo. Illustrated. 8/- net.

"It will be found useful by teachers, students, and electrical engineers
in general practice."—*Electrical Engineer.*

Internal Wiring of Buildings.

By **H. M. Leaf, M.I.M.E., etc.** *2nd Edition. Crown 8vo. 3/6 net.*

Searchlights: Their Theory, Construction and Application.

By **F. Nerz.** Translated from the German by **Charles
Rodgers.** *Illustrated. Royal 8vo. 7/6 net.*

Electric Wiremen's Manuals. (*See p. 3*)

Electro-Chemistry, etc.

Experimental Electro-Chemistry.

By **N. Monroe Hopkins, Ph.D.**, Assistant Professor of
Chemistry in The George Washington University,
Washington, D.C.

With 130 Illustrations. Demy 8vo. 12/- net.

Electro-Metallurgy.

By **J. B. C. Kershaw, F.I.C.**

With 61 Illustrations. Ex. Crown 8vo. 6/- net.

Electric Furnaces. By **J. Wright.**

New 2nd Edition, Revised and Enlarged. With 67 Illustrations. Demy 8vo. 8/6 net.

CONTENTS:—Introductory and General. Efficiency of the Electric
Furnace. Arc Furnaces. Resistance Furnaces. Carbide Furnaces.
Smelting and Ore Reduction in the Electric Furnace. Dis-
tillation of Metals. Electrolytic Furnaces. Laboratory Furnaces
and Dental Muffles. Tube Furnaces. Glass Manufacture in the Electric
Furnace. Electrodes and Terminal Connections. Furnace Thermometry.

Lighting

Electric Lamps.

By **Maurice Solomon, A.C.G.I., A.M.I.E.E.**

Illustrated. Ex. Crown 8vo. 6/- net.

The Art of Illumination.

By **Louis Bell, Ph.D., M.A.I.E.E.**

Illustrated. 345 pages. Demy 8vo. 10/6 net.

Town Gas and its Uses for the Production of Light, Heat, and Motive Power.

By **W. H. Y. Webber, C.E.**

With 71 Illustrations. Ex. Crown 8vo. 6/- net.

Thermodynamics

Entropy : Or, Thermodynamics from an Engineer's Standpoint, and the Reversibility of Thermodynamics.

By **James Swinburne, M.Inst.C.E., M.I.E.E., etc.**

Illustrated with Diagrams. Crown 8vo. 4/6 net.

Applied Thermodynamics for Engineers.

By **William D. Ennis, M.E., M.Am.Soc.M.E.**, Professor of Mechanical Engineering in the Polytechnic Institute of Brooklyn. *With 316 Illustrations. Royal 8vo. 21/- net.*

Technical Thermodynamics.

By **Dr. Gustav Zeuner.** First English Edition. From the fifth complete and revised edition of "Grundzüge der Mechanischen Wärmetheorie."

VOL. I.—Fundamental Laws of Thermodynamics ; Theory of Gases.

VOL. II.—The Theory of Vapours.

Authorised translation by **J. F. Klein, D.E.**, Professor of Mechanical Engineering, Lehigh University.

Illustrated. 2 vo. 36/- net.

A Text-Book of Thermodynamics (with special reference to Chemistry).

By **J. R. Partington, M.Sc.**, of the University of Manchester.

544 + x pages. 91 Diagrams. Demy 8vo. 14/- net.

Experimental and Theoretical Applications of Thermodynamics to Chemistry.

By **Professor Walter Nernst**, University of Berlin.

Ex. Crown 8vo. 5/- net.

Principles of Thermodynamics.

By **G. A. Goodenough, M.E.** *Second Edition, Revised. Price 14/- net.*

Physics and Chemistry.

Physics and Chemistry

Some Fundamental Problems of Chemistry, Old and New.

By **E. A. Letts, D.Sc.**, Professor of Chemistry in the Queen's University, Belfast. *Demy 8vo. 223 + xiii pages. 44 Illustrations. 7/6 net.*

The Silicates in Chemistry and Commerce.

By **Drs. W. and D. Asch.** Translated with critical notes and some additions by **A. B. Searle.**

400 + xx pages. Royal 8vo. 21/- net.

CONTENTS:—The Chemistry of Carbon and Silicon. Historical Review of Existing Theories concerning the Constitution of the Alumino-silicates and other Silicates. Critical Examination of Existing Theories concerning Alumino-silicates. A Hypothesis concerning the Bonding of the Atoms in Alumino-silicates and Allied Compounds. The Consequences of the "Hexite-Pentite Theory," and the Facts: (I.) The Reactions during Double Decomposition; (II.) The Genetic Relationship between the various Alumino-silicates; (III.) The Possibility of a Chemical System of Alumino-silicates; (IV.) The Variable Chemical Behaviour of part of the Aluminium in Kaolin, Nepheline, and in the Epidotes; (V.) The Minimum Molecular Weight of Alumino-silicates; (VI.) The Constitution of Andesite; (VII.) The Possibility of Isomerism; (VIII.) Water of Crystallisation and of Constitution: Basic and Acid Water; (IX.) Prognoses; (X.) The Constitution of the Complexes of Molybdenum and Tungsten; (XI.) The Constitution of Clays; (XII.) Ultramarines; (XIII.) A New Theory of Hydraulic Binding Materials and particularly of Portland Cements; (XIV.) A New Theory of the Porcelain Cements as used for Dental Fillings; (XV.) A New Theory of Glass, Glazes, and Porcelain; (XVI.) The Hexite-Pentite Theory as a General Theory of Chemical Compounds. The Conversion of the H.P. Theory into a Stereo-chemical Theory and the combination of the latter with the modern theory of the Structure of Crystals. Summary and Conclusions. Bibliography of references mentioned in Text. Appendix. Formulæ and Analyses. Bibliography of references in Appendix.

Industrial Chemistry: A Manual for the Student and Manufacturer. *Second Edition, Revised and Enlarged.*

EDITED BY **Allen Rogers**, in charge of Industrial Chemistry, Pratt Institute, Brooklyn, N.Y.; and **Alfred B. Aubert**, formerly Professor of Chemistry in the University of Maine, in collaboration with many experts, containing 340 Illustrations. *Royal 8vo. 24/- net.*

CONTENTS:—General Processes. Materials of Construction. Water for Industrial Purposes. Fluids. Producer Gas. Power Transmission. Boilers, Engines and Motors. Sulphuric Acid. Nitric Acid. Salt and Hydrochloric Acid. Commercial Chemicals. Chlorine and Allied Products. Electrochemical Industries. Lime, Cement and Plaster. Clay, Bricks and Pottery. Glass. Dutch Process White Lead. Sublimed White Lead. Pigments, Oils and Paints. The Metallurgy

Physics and Chemistry—continued.

Industrial Chemistry—continued.

of Iron and Steel. Fertilizers. Illuminating Gas. Coal Tar and its Distillation Products. The Petroleum Industry. The Destructive Distillation of Wood. Oils, Fats and Waxes. Lubricating Oils. Soaps, Glycerine and Candles. Laundering. Essential Oils, Synthetic Perfumes, and Flavouring Materials. Resins, Oleo-Resins, Gum-Resins and Gums. Varnish. Sugar. Starch, Glucose, Dextrin and Gluten. Brewing and Malting. Wine Making. Distilled Liquors. Textiles. Dyestuffs and Their Application. The Art of Paper Making. Explosives. Leather. Vegetable Tanning Materials. Glue and Gelatine. Casein.

The Application of Physico-Chemical Theory to Technical Processes and Manufacturing Methods.

By **Dr. R. Kremann**. Translated by **H. E. Potts, M.Sc.**
Demy 8vo. 8/6 net. (See p. 48.)

An Introduction to the Study of Physical Metallurgy. By **Walter Rosenhain, B.A., D.Sc., F.R.S.** 350 + xvi pages. 140 Illustrations. *Demy 8vo. 10/6 net.*

CONTENTS:—The Structure and Constitution of Metals and Alloys. The Microscopic Examination of Metals. The Metallurgical Microscope. The Micro-Structure of Pure Metals and of Alloys. The Thermal Study of Alloys. The Constitutional Diagram and the Physical Properties of Alloys. Typical Alloy Systems. The Iron-Carbon System. The Properties of Metals as Related to their Structure and Constitution. The Mechanical Testing of Metals. The Mechanical Testing of Metals (*contd.*). The Effect of Strain on the Structure of Metals. The Thermal Treatment of Metals. The Mechanical Treatment of Metals, including Casting. Defects and Failures in Metals and Alloys.

The Chemistry and Technology of Printing Inks.

By **Norman Underwood** and **Thomas V. Sullivan**.
Medium 8vo. 12/6 net.

Problems in Physical Chemistry. With Practical Applications.

By **E. B. R. Prideaux, M.A., D.Sc.**, with a Preface by **F. G. Donnan, M.A., Ph.D., F.R.S.** 7/6 net.

Chemical Theory and Calculations: An Elementary Text-book.

By **Forsyth J. Wilson, D.Sc. (Edin.), Ph.D. (Leipzig)**,
and **Isodor M. Heilbron, Ph.D. (Leipzig), F.I.C., A.R.T.C.** 2/6 net.

Physics and Chemistry—continued.

Electric Arc Phenomena.

By **E. Rasch**. Translated by **K. Tornberg**.

Demy 8vo. 52 Illustrations. 8/6 net.

CONTENTS:—General Outline of Electric Arc Phenomena. Typical Carl on Arc. Electrode Materials and their Physical Properties. Theory of Electric Discharges through Gases. Spark Discharges. Empirical Results. Voltage and Current Conditions in the Arc. Distribution of Energy in the Arc. Efficiency of Commercial Types of Arc.

Theory of Measurements.

By **James S. Stevens**, Professor of Physics in the University of Maine. *Ex. Cr. 8vo. 6/- net.*

A manual for students in physics designed for use either as a text-book or as a laboratory guide.

Chemical Calculations.

By **R. Harman Ashley, Ph.D.** *Ex. Crown 8vo. 8/6 net.*

CONTENTS:—Ratios. Approximate Numbers. Interpolation. Heat. Specific Gravity. Gas Calculations. Calculation of Atomic Weights and Formulas. Gravimetric Analysis. Volumetric Analysis. Use of Specific Gravity Tables and Acid Calculations.

Atoms. By **Jean Perrin**. Translated by **D. LI. Hammick**.

Demy 8vo. 16 Illustrations. 5/- net.

CONTENTS:—Chemistry and the Atomic Theory. Molecular Agitation. The Brownian Movement—Emulsions. The Laws of the Brownian Movement. Fluctuations. Light and Quanta. The Atom of Electricity. The Genesis and Destruction of Atoms. Index.

The Universe and the Atom.

The Ether Constitution, Creation and Structure of Atoms, Gravitation, and Electricity, Kinetically Explained.

By **Marion Erwin, C.E.** *Demy 8vo. Illustrated. 8/6 net.*

CONTENTS.—Part I., First Principles. Part II., The Pan Cycle Hypothesis: Invisible Composition Light Waves, the Warp and Woof of the Ether Structure and of All Things Material.

Radio-Activity and Geology.

By **John Joly, M.A., Sc.D., F.R.S.**, Professor of Geology and Mineralogy in the University of Dublin.

Crown 8vo. 7/6 net.

The Corpuscular Theory of Matter.

By **Sir J. J. Thomson, M.A., F.R.S., D.Sc., LL.D., Ph.D.**, Professor of Experimental Physics, Cambridge, and Professor of Natural Philosophy at the Royal Institution, London. *Demy 8vo. 7/6 net.*

Electricity and Matter.

By **Sir J. J. Thomson, M.A., F.R.S., D.Sc., LL.D., Ph.D.**

Crown 8vo. 5/- net.

Physics and Chemistry—continued.

The Discharge of Electricity through Gases.

By **Sir J. J. Thomson, M.A., F.R.S., D.Sc., LL.D., Ph.D.**
Crown 8vo. 4/6 net.

The Electrical Nature of Matter and Radioactivity.

By **H. C. Jones**, Professor of Physical Chemistry in the
Johns Hopkins University.
Second Edition. Revised and largely rewritten. Demy 8vo. 8/- net.

The Theory of Ionization of Gases by Collision.

By **John S. Townsend, M.A., F.R.S.**, Wykeham Professor of Physics in the University of Oxford.
Crown 8vo. 3/6 net.

Radio-Active Transformations.

By **Ernest Rutherford, F.R.S.**, Professor of Physics at
the McGill University, Montreal, Canada.
Illustrated. Demy 8vo. 16/- net.

Principles of Microscopy.

BEING AN INTRODUCTION TO WORK WITH THE MICROSCOPE.
By **Sir A. E. Wright, M.D., F.R.S., D.Sc., Dublin,**
(Honoris Causa), **F.R.C.S.I. (Hon.).**
With many Illustrations and Coloured Plates. Super Royal 8vo. 21/- net.

Experimental and Theoretical Applications of Thermodynamics to Chemistry.

By **Professor Walter Nernst**, University of Berlin.
15s. Crown 8vo. 5/- net.

Vapours for Heat Engines.

By **William D. Ennis, M.E., M.Am.Soc.M.E.**, Professor
of Mechanical Engineering in the Polytechnic Institute
of Brooklyn, Author of "Applied Thermodynamics for
Engineers," etc.
With 21 Tables and 17 Illustrations. Demy 8vo. 6/- net.

The Hydrogenation of Oils. Catalyzers and Catalysis and the Generation of Hydrogen.

By **Carleton Ellis, S.B.**
310 pages. 145 Illustrations. Royal 8vo. 16/- net.

Physics and Chemistry—continued.

A Text-Book of Physics.

By **H. E. Hurst, B.A., B.Sc.**, Hertford College, Oxford, late Demonstrator in Physics in the University Museum, Oxford, and **R. T. Lattey, M.A.**, Royal Naval College, Dartmouth, late Demonstrator in Physics in the University Museum, Oxford.

Illustrations and Diagrams. Demy 8vo. 8/6 net.

Now published also in three volumes, at the request of many teachers. Each part is sold separately.

PART I.—DYNAMICS AND HEAT. 3/6 net.

PART II.—LIGHT AND SOUND. 3/6 net.

PART III.—MAGNETISM AND ELECTRICITY. 4/- net.

Introduction to the Chemistry and Physics of Building Materials.

By **Alan E. Munby, M.A. (Cantab.)**. *Extra Crown 8vo. 6/- net.*

Exercises in Physical Chemistry.

By **Dr. W. A. Roth**, Professor of Chemistry in the University of Greifswald. Authorised Translation by **A. T. Cameron, M.A., B.Sc.**, of the University of Manitoba. *Illustrated. Demy 8vo. 6/- net.*

The Chemistry of Paints and Paint Vehicles.

By **C. H. Hall, B.S.** *Crown 8vo. 8/- net.*

Liquid Air and the Liquefaction of Gases. *Second Edition.*

By **T. O'Connor Sloane, M.A., M.E., Ph.D.**

Illustrated. Demy 8vo. 10/6 net.

Chemical Re-agents: Their Purity and Tests.

A NEW AND IMPROVED TEXT, BASED ON AND REPLACING THE LATEST EDITION OF KRAUCH'S MANUAL.

By **E. Merck**. Translated by **H. Schenck**. 250 pages. *Demy 8vo. 6/- net.*

Van Nostrand's Chemical Annual.

A HANDBOOK OF USEFUL DATA FOR ANALYTICAL, MANUFACTURING, AND INVESTIGATING CHEMISTS, AND CHEMICAL STUDENTS.

Edited by **John C. Olsen, M.A., Ph.D.**, Professor of Analytical Chemistry, Polytechnic Institute, Brooklyn; with the co-operation of Eminent Chemists. *Nearly 100 Tables. Crown 8vo. 12/6 net.*

Physics and Chemistry—continued.

Text-Book of Elementary Chemistry.

By **F. Mollwo Perkin, Ph.D., F.I.C., F.C.S.,** and
Eleanor M. Jagers.

Illustrated. Crown 8vo. 3/- net.

CONTENTS:—Examination of Water. Metric System. Distillation. Thermometers. Freezing Points. Boiling Points. Melting Points. The Atmosphere. Chemical Properties of the Atmosphere. Chemical Properties of Water. Hydrogen and Oxygen. Quantitative Examination of Chalk. Carbon and its Oxides and Compounds with Hydrogen. Flame and Combustion. Compounds of Nitrogen. Hydrochloric Acid and the Halogens. Sulphur and its Compounds. Phosphorus and Phosphorus Compounds. The Metals. Appendix. Index.

Practical Methods of Inorganic Chemistry.

By **F. Mollwo Perkin, Ph.D.**

Illustrated. Crown 8vo. 2/6 net.

Contemporary Chemistry.

By **E. E. Fournier D'Albe, B.Sc., A.R.C.S., M.R.I.A.,**
Author of "The Electron Theory," etc. 4/- net.

A New Era in Chemistry: Some of the more important developments in general chemistry during the last quarter of a century.

By **Harry C. Jones.**

326 + xii pages. *Ex. Crown 8vo. 8/6 net.*

The Identification of Organic Compounds.

By **G. B. Neave, M.A., D.Sc.,** and **I. M. Heilbron, Ph.D., F.I.C., etc.** *Crown 8vo. 4/- net.*

Detection of Common Food Adulterants.

By **Prof. E. M. Bruce.** *Crown 8vo. 5/- net.*

A handbook for health officers, food inspectors, chemistry teachers and students.

The Chemistry of Dyeing and Bleaching of Vegetable Fibrous Materials.

By **Julius Hübner, M.Sc.Tech., F.I.C.**

Demy 8vo. Illustrated. 14/- net.

CONTENTS: The Vegetable Fibres. Water. Chemicals and Mordants. Bleaching. Mercerising. Mineral Colours. The Natural Colouring Matters. Basic Cotton Dyestuffs. Substantive Cotton Dyestuffs. Sulphur Dyestuffs. Acid and Resorcline Dyestuffs. Insoluble Azo- Colours, produced on the fibre. The Vat Dyestuffs. Mordant Dyestuffs. Colours produced on the fibre by Oxidation. Dyeing Machinery. Estimation of the Value of Dyestuffs. Appendix. Index.

Chemistry of the Oil Industries.

By **J. E. Southcombe, M.Sc.**, Lecturer on Oils and Fats,
Royal Salford Technical Institute, etc. 7/6 net. (See p. 18.)

The Chemistry of the Coal Tar Dyes.

By **Irving W. Fay, Ph.D. (Berlin)**.
Demy 8vo. 470 pages. 16/- net.

The Chemistry of the Rubber Industry.

By **Harold E. Potts, M.Sc.** Member International Rubber
Testing Committee. *Demy 8vo. Illustrated. 5/- net. Second
Impression.*

CONTENTS:—The Colloidal State. Raw Rubber. Gutta-Percha and
Balata. Mixing. Vulcanisation, History. Vulcanised Rubber.

The Colloidal and Crystalloidal State of Matter.

By **H. E. Potts, M.Sc.**, and **W. J. Breitland**. Translated
from the German of **Professor P. Rohland**.
Illustrated. Crown 8vo. 4/- net.

The Nitrocellulose Industry.

By **Edward Chauncey Warden, Ph.C., M.A., F.C.S.**
2 vols. 1,240 pages. 324 Illustrations. Sm. 4to. 42/- net.

A compendium of the history, chemistry, manufacture, commercial
application and analysis of nitrates, acetates and Xanthates of cellulose as
applied to the peaceful arts, with a chapter on gun cotton, smokeless
powder and explosive cellulose nitrates.

Materials for Permanent Painting.

By **M. Toch, F.C.S.**
Frontispiece in Colour and other Illustrations. Crown 8vo. 7/6 net.
A manual for manufacturers, art dealers, artists and collectors,
explaining the composition of the materials used in painting.

Cement, Concrete, and Bricks, The Chemistry of. By **A. B. Searle**.

Demy 8vo. Illustrated. 10/6 net.

CONTENTS: The Raw Materials for Cements. Methods of Cement Manu-
facture. The Chemical and Physical Changes in Cements. The Changes
which occur in Setting and Hardening. Testing the Properties of Cement.
The Components of Concrete and their Properties. The Preparation of
Concrete. Reinforced Concrete. Special Properties of Concrete. Testing
Concrete. The Raw Materials for Bricks. Methods of Brickmaking.
The Chemical and other Changes in Drying and Burning Bricks. The
Properties of Bricks. Siliceous Bricks. Basic and Neutral Bricks. Index.

Mathematics.

Mathematics

The Theory of Proportion.

By **M. J. M. Hill, M.A., LL.D., Sc.D., F.R.S.**

Demy 8vo. 108 + xii pages. 15 Figures. 5/- net.

CONTENTS:—Magnitudes of the same Kind. Propositions relating to Magnitudes and their Multiples. The Relations between Multiples of the same Magnitude. Commensurable Magnitudes. Magnitudes of the same Kind which are not Multiples of the same Magnitude. Incommensurable Magnitudes. Extension of the Idea of Number. On the Ratios of Magnitudes which have no Common Measure. Properties of Equal Ratios. First Group of Propositions. Second Group of Propositions. Third Group of Propositions—Geometrical Applications of Stolz's Theorem. Further Remarks on Irrational Numbers. The Existence of the Fourth Proportional. Commentary on the Fifth Book of Euclid's Elements.

The Calculus and its Applications. A Practical Treatise for Beginners, especially Engineering Students. With over 400 examples, many of them fully worked out.

By **Robert Gordon Blaine, M.E., A.M.Inst.C.E.,**
Formerly Lecturer at the City Guilds' Technical College.
Author of "Lessons in Practical Mechanics," "The Slide Rule," etc. *Crown 8vo. 4/6 net.*

Integration by Trigonometric and Imaginary Substitution. By Charles O. Gunther, with an Introduction by J. Burkett Webb, C.E. Demy 8vo. 5/- net.

Mathematics for the Practical Man.

By **George Howe, M.E.**

Crown 8vo. 5/- net.

A short work explaining all the elements of Algebra, Geometry, Trigonometry, Logarithms, Co-ordinate Geometry, and Calculus.

Quaternions, as the Result of Algebraic Operations.

By **Arthur Latham Baker, Ph.D.**

Ex. Crown 8vo. 6/- net.

The Practical Mechanic's Handbook.

By **F. E. Smith. 4/6 net.**

CONTENTS:—Arithmetic. Arithmetical Signs and Characters and Explanation of Solving Formula. Mensuration. How the Dimensions, Measurements, and Weight of Different Shaped Vessels are Found. The Primary or Simple Machines. Strength of Materials and Questions Relating to Stress.

Manufacture and Industries

Manufacture and Industries

Purchasing: Its Economic Aspects and Proper Methods.

By **H. B. Twyford**, of the Otis Elevator Company.

112 Charts, Diagrams and Forms. Large Demy 8vo, 252 pp. 12/6 net.

The subject is treated as only an experienced buyer could treat it, and it deals with purchases in practically all lines of business. The author quotes an experienced business man as saying that "successful foundation for new enterprises, the growth of established undertakings, and their accretion to their resources is in a large measure dependent on the importance attached to, and the careful thought given to, the expenditure of all money for capital purposes, production, and supplies." To set forth at least the general principles of this successful purchasing is the task which the author has set himself.

Applications of Physico-Chemical Theory to Technical Processes and Manufacturing Methods.

By **Dr. R. Kremann**. Translated into English and edited by **H. E. Potts, M.Sc.** Demy 8vo. 8/6 net.

CONTENTS:—The Two Fundamental Laws of the Mechanical Theory of Heat. Reaction-Velocity and Catalytes. Other Special Applications of the Law of Mass Action. The Influence of Temperature on the Equilibrium-Constant. Dissociation Pressure. Application of the Phase Rule. The Application of the Phase Rule to Solid-Liquid Systems. Transformation Phenomena in Hydraulic Binding Agents. Other Applications of the Phase Rule. The Distribution Law. Adsorption Compounds. Reciprocal Pairs of Salts.

Chemistry of the Oil Industries.

By **J. E. Southcombe, M.Sc.**, Lecturer on Oils and Fats, Royal Salford Technical Institute, etc. 7/6 net.

"OUTLINES OF INDUSTRIAL CHEMISTRY."

CONTENTS:—Preface. Introductory Organic Chemistry. Mineral Oils. Petroleum and Shale. Mineral Oil Refining. Natural Sources and Methods of Preparation of the Saponifiable Oils and Fats. Impurities occurring in Crude Oils and Fats and the Technical Methods of Removing them. Composition and Properties of the Saponifiable Oils and Fats in General. Composition and Properties of the Individual Oils and Fats of Commercial Importance. The Natural Waxes, their Composition and Properties. Analytical Methods. Industrial Applications of Fats and Oils. Burning Oils. Edible Oils and Margarines. Polymerised, Boiled and Blown Oils. Turkey-Red Oils. Saponification of Fats and Oils on a Technical Scale. The Distillation of Fatty Acids. Oleines and Stearines. Candle Manufacture. Soap-Making. Glycerine. Conclusion: Scientific and Technical Research on Problems in the Oil and Related Industries. Literature.

The Manufacture of Paper.

By **R. W. Sindall, F.C.S.** *Illustrated. Ex. Crown 8vo. 6/- net.*
CONTENTS:—Preface. List of Illustrations. Historical Notice, Cellulose and Paper-Making Fibres. The Manufacture of Paper from Rags, Esparto and Straw. Wood Pulp and Wood Pulp Papers. Brown Papers and Boards. Special kinds of Paper. Chemicals used in Paper-making. The Process of "Beating." The Dyeing and Colouring of Paper Pulp. Paper Mill Machinery. The Deterioration of Paper. Bibliography. Index.

Mineral and Aerated Waters, and the Machinery for their Manufacture.

By **C. Answorth Mitchell, B.A. (Oxon.), F.I.C.**
Illustrated. Demy 8vo. 8/6 net.

Glass Manufacture.

By **Walter Rosenhain**, Superintendent of the Department of Metallurgy in the National Physical Laboratory.

Illustrated. Ex. Crown 8vo. 6/- net.

CONTENTS:—Preface. Physical and Chemical Properties of Glass. The Raw Materials of Glass Manufacture. Crucibles. Furnaces for the Fusion of Glass. The Process of Fusion. Processes used in the Working of Glass. Bottle Glass. Blown and Pressed Glass. Rolled or Plate Glass. Sheet and Crown Glass. Coloured Glass. Optical Glass. Miscellaneous Products. Appendix.

Decorative Glass Processes.

By **Arthur Louis Duthie.** *Illustrated. Ex. Crown 8vo. 6/- net.*

Commercial Paints and Painting. A Handbook for Architects, Engineers, Property Owners, Painters and Decorators, etc.

By **Arthur Seymour Jennings.**

224 + vii pages. 47 Illustrations. *Extra Crown 8vo. 6/- net.*

The Manufacture of Leather.

By **Hugh Garner Bennett, M.Sc., F.C.S.**, Member of the International Association of Leather Trade Chemists.

Demy 8vo. Illustrated. 16/- net.

Cotton Seed Products.

A MANUAL OF THE TREATMENT OF COTTON SEED FOR ITS PRODUCTS AND THEIR UTILIZATION IN THE ARTS.

By **Leebert Lloyd Lamborn**, Member of the American Chemical Society; Member of the Society of Chemical Industry. *With 79 Illustrations and a Map. Demy 8vo. 12/6 net.*

Linseed Oil and other Seed Oils.

An Industrial Manual by **William D. Ennis, M.E., M.Am.Soc.M.E.**, Professor of Mechanical Engineering, Polytechnic Institute of Brooklyn. *Medium 8vo. Illustrated. 16/- net.*

Textiles and their Manufacture.

By **Aldred F. Barker, M.Sc.** *Illustrated. Ex. Crown 8vo. 6/- net.*

Materials used in Sizing.

By **W. F. A. Ermen.** *5/- net.*

CONTENTS:—The Starches and other Agglutinants. Weighting Materials. Softening Ingredients. Antiseptics. Analysis of Sized Warps and Cloth. The Preparation of Normal Volumetric Solutions. Tables.

Solvents, Oils, Gums, Waxes, and Allied

Substances. By **F. S. Hyde, Ph.B.** *Demy 8vo. 8/6 net.*

Glues and Gelatine.

A PRACTICAL TREATISE ON THE METHODS OF TESTING AND USE. By **R. Livingston Fernbach.**
Illustrated. Demy 8vo. 10/6 net.

Agglutinants and Adhesives of all Kinds

for all Purposes. By **H. C. Standage.** *Demy 8vo. 6/- net.*

Cork: Its Origin and Industrial Uses.

By **Gilbert E. Stecher.** *Crown 8vo. 4/6 net.*

The Chemistry of Dyeing and Bleaching of Vegetable Fibrous Material.

By **Julius Hübner, M.Sc.Tech., F.I.C.** (See p. 45)

The Chemistry and Technology of Printing

Inks. By **Norman Underwood** and **Thomas V. Sullivan.**
Medium 8vo. 12/6 net.

The Chemistry of the Rubber Industry.

By **Harold E. Potts, M.Sc.** *5/- net. (See p. 46.)*

India-Rubber and its Manufacture, with Chapters on Gutta-Percha and Balata.

By **H. L. Terry, F.I.C., A.I.M.M.**

Manufacture and Industries—continued.

The Nitrocellulose Industry.

By **Edward Chauncey Warden, Ph.C., M.A., F.C.S.**

2 vols. 42/- net. (See p. 46.)

Materials for Permanent Painting.

By **M. Toch, F.C.S.** *Frontispiece in Colour and other Illustrations.*
Crown 8vo. 7/6 net.

A manual for manufacturers, art dealers, artists and collectors explaining the composition of the materials used in painting.

The Basic Open-Hearth Steel Process:

By **Carl Dichmann.** (See p. 17.)

Wood Pulp. By **Charles F. Cross, B.Sc., F.I.C.; E. J.**

Bevan, F.I.C., and R. W. Sindall, F.C.S. *Illustrated. 6/- net.*

CONTENTS.—The Structural Elements of Wood. Cellulose as a Chemical. Sources of Supply. Mechanical Wood Pulp. Chemical Wood Pulp. The Bleaching of Wood Pulp. News and Printings. Wood Pulp Boards. Utilisation of Wood Waste. Testing of Wood Pulp for Moisture. Wood Pulp and the Textile Industries. Bibliography. Index.

History of the Frozen Meat Trade.

By **J. C. Critchell and J. Raymond.**

Illustrated. Demy 8vo. 10/6 net.

Arts and Crafts

Simple Jewellery.

A PRACTICAL HANDBOOK WITH CERTAIN ELEMENTARY METHODS OF DESIGN AND CONSTRUCTION, WRITTEN FOR THE USE OF CRAFTSMEN, DESIGNERS, STUDENTS AND TEACHERS. By **R. Ll. B. Rathbone.**

Ex. Crown 8vo. 94 Illustrations. Second Impression. 6/- net.

The Potter's Craft. A PRACTICAL GUIDE FOR THE STUDIO

AND WORKSHOP. By **Charles F. Binns**, late Superintendent Royal Porcelain Works, Worcester. *With 42 Illustrations.*

Crown 8vo. 6/- net.

Precious Stones.

By **W. Goodchild, M.B., B.Ch.** *With 42 Illustrations.*

WITH A CHAPTER ON ARTIFICIAL STONES. By **Robert Dykes.** *Illustrated. Ex. Crown 8vo. 6/- net.*

Enamelling. On the Theory and Practice of *Third Edition.*

Art Enamelling upon Metals. By **Henry Cunyng-**
hame, M.A., C.B. *Two Coloured Plates and 20 Illustrations.*

Crown 8vo. 6/- net.

Useful Handbooks and Tables.

Useful Handbooks and Tables

The Practical Mechanic's Handbook.

By **F. E. Smith.** (*See p. 47.*)

Materials used in Sizing.

By **W. F. A. Ermen.** (*See p. 50.*)

Reference Book for Statical Calculations.

By **Francis Ruff.**

Crown 8vo. 160 Illustrations. Charts and Diagrams. 4/- net.

Handbook for the Care and Operation of

Naval Machinery. By **Lieut. H. C. Dinger, U.S. Navy.**

Cloth. 302 Pages. 124 Illustrations. Pocket size. Price 7/6 net.

Pricing of Quantities.

SHOWING A PRACTICAL SYSTEM OF PREPARING AN ESTIMATE FROM BILLS OF QUANTITIES. By **George Stephenson,** Author of "Repairs," "Quantities," etc.

Demy 8vo. 3/6 net.

The Law affecting Engineers.

By **W. Valentine Ball, M.A. (Cantab.),** Barrister-at-Law, Joint Editor of "Emden's Building Contracts."

Demy 8vo. 10/6 net.

A concise statement of the powers and duties of an engineer, as between employer and contractor, as arbitrator and as expert witness, together with an outline of the law relating to engineering contracts, and an appendix of forms of contract, with explanatory notes.

Tables of Multiplication, Division and Pro-

portion: For the Ready Calculation of Quantities and Costs, Estimates, Weights and Strengths, Wages and Wage Premiums.

By **Prof. R. H. Smith, A.M.Inst.C.E., M.I.E.E., etc.** 2/6 net.

Lettering.

9th Edition,

Revised and Enlarged.

FOR DRAUGHTSMEN, ENGINEERS AND STUDENTS.

By **C. W. Reinhardt.** 4/- net.

The New Steam Tables. Calculated from Professor Callendar's Researches.

By **Professor C. A. M. Smith, M.Sc.,** and **A. G. Warren,**

Natural History, Botany, Nature Study, etc.

Natural History, Botany, Nature Study, etc.

Extinct Animals.

By **Sir E. Ray Lankester, F.R.S.**

With a Portrait of the Author and 218 other Illustrations. New and Revised Edition. Ex. Crown 8vo. 3/6 net.

Economic Zoology and Entomology.

By **Vernon L. Kellogg and C. W. Doane.**

Crown 8vo. 6/6 net.

The authors are well known as clear and precise exponents of their subject. In this text-book they have produced an introduction both to general zoology as well as to that specific phase of it called "economic."

The first chapters introduce the reader to general facts of animal structure and life and are arranged on the basis of accepted pedagogic principles. The latter chapters, arranged on a basis of animal classification proceeding from the simplest to the nine highly developed groups, include not only general facts pertaining to the groups treated, but introduce and give general attention to the economic relations of the various members of the groups. Finally, there is presented a form of encyclopædic treatment of a wide range of facts wholly economic in aspect.

The Stone Age in North America.

By **Warren K. Moorhead.**

In 2 Volumes. 900 pages. With about 700 Illustrations, including 6 in Colour, 12 in Photogravure and Several Maps. Crown 4to. 31s. 6d. net.

An archaeological encyclopædia of the implements, ornaments, weapons, utensils, etc., of the prehistoric tribes of North America. The work is the result of twenty years' exploration and study.

Distribution and Origin of Life in America.

By **R. F. Scharff, B.Sc., Ph.D., F.L.S.**

Illustrated. Large Crown 8vo. 10/6 net.

European Animals : Their Geological History and their Geographical Distribution.

By **R. F. Scharff, B.Sc., Ph.D., F.L.S.**

Illustrated. Demy 8vo. 7/6 net.

The Living Plant : A Description and Interpretation of its Functions and Structure.

By **William F. Ganong, Ph.D. Illustrated. 465 + xii pages. 15/- net.**

The Nature Student's Note Book.

By **Rev. Canon Steward, M.A., and Alice E. Mitchell.**

Containing Nature Notes, Diary, Classification of Plants, Trees, Animals

**Natural History, Botany, Nature Study,
etc.—continued.**

**Life Histories of Northern Animals. An
Account of the Mammals of Manitoba.**

By **Ernest Thompson Seton**, Naturalist to the Government of Manitoba.

In two volumes. Large 8vo. Over 600 pages each. With 70 Maps and 600 Drawings by the Author. 73/6 net.

Influences of Geographic Environment.

By **E. C. Semple**, Author of "American History and its Geographic Conditions."

Med. 8vo. 700 pages. 18/- net.

Outlines of Evolutionary Biology.

By **Arthur Dendy, D.Sc., F.R.S.**, Professor of Zoology in the University of London (King's College); Zoological Secretary of the Linnean Society of London; Honorary Member of the New Zealand Institute; formerly Professor of Biology in the Canterbury College (University of New Zealand), and Professor of Zoology in the South African College, Cape Town. *Second Edition, enlarged. Third Impression, with a Glossary. Illustrated. 12/6 net.*

CONTENTS:—The Structure and Functions of Organisms. The Cell Theory. The Evolution of Sex. Variation and Heredity. The Theory and Evidence of Organic Evolution. Adaptation. Factors of Organic Evolution. Glossary of Technical Terms.

Plant Physiology and Ecology.

By **Frederic Edward Clements, Ph.D.**, Professor of Botany in the University of Minnesota. With 125 Illustrations.

Demy 8vo. 8/6 net.

Indian Trees.

AN ACCOUNT OF TREES, SHRUBS, WOODY CLIMBERS, BAMBOOS AND PALMS, INDIGENOUS OR COMMONLY CULTIVATED IN THE BRITISH INDIAN EMPIRE.

By **Sir Dietrich Brandis, K.C.I.E., Ph.D. (Bonn), LL.D. (Edin.), F.R.S., F.L.S., F.R.G.S.**, and Hon. Member of the Royal Scottish Arboricultural Society, of the Society of American Foresters, and of the Pharmaceutical Society of Great Britain. Assisted by Indian Foresters.

Illustrated. Demy 8vo. 16/- net. Third Impression.

Agriculture and Farming

Agriculture and Farming

The Potato : A Compilation of Information from every available Source.

By **Eugene H. Grubb and W. S. Guilford.**

Illustrated. Demy 8vo. 8/6 net.

Poultry Management on a Farm : An Account of 'Three Years' Work, with practical Results and Balance Sheets. By **Walter Palmer.**

Illustrated. Demy 8vo. 1/- net.

Dairy Laboratory Guide.

By **C. W. Melick, B.S.A., M.S.** *Crown 8vo, with 52 Illustrations. 5/- net.*

Wool Growing and the Tariff.

A STUDY IN THE ECONOMIC HISTORY OF THE UNITED STATES.

By **Chester Whitney Wright, Ph.D.** *Demy 8vo. 8/6 net.*

Soils and Manures. By **J. Alan Murray, B.Sc.**

Illustrated. Extra Cr. 8vo. 6/- net.

CONTENTS.—Preface. Introductory. The Origin of Soils. Physical Properties of Soils. Chemistry of Soils. Biology of Soils. Fertility. Principles of Manuring. Phosphatic Manures. Phospho-Nitrogenous Manures. Nitrogenous Manures. Potash Manures. Compound and Miscellaneous Manures. General Manures. Farmyard Manure. Valuation of Manures. Composition and Manurial Value of Various Farm Foods. Index.

Soils: How to Handle and Improve Them.

By **S. W. Fletcher.**

Upwards of 100 Illustrations. Demy 8vo. 8/6 net.

To Work a Grass Holding at a Living Profit, and the Cheap Cottage Problem.

By **H. B. M. Buchanan, B.A.** *Crown 8vo. 1/- net.*

The First Book of Farming.

By **Charles L. Goodrich.** *With 85 Illustrations. Crown 8vo. 4/6 net.*

Farm Management.

By **F. W. Card,** Professor of Agriculture.

66 Full-page Illustrations and numerous useful Tables and Returns. Demy 8vo. 8/6 net.

Agriculture and Farming—continued.

Farm Animals : How to Breed, Feed, Care for and Use Them. By **E. V. Willcox, Ph.D., M.A., U.S.A.**
Department of Agriculture.

With over 60 full-page Illustrations. Demy 8vo. 8/6 net.

Law, Patents, etc.

Building in London.

By **Horace Cubitt, A.R.I.B.A., etc.**

Illustrated, with diagrams. Royal 8vo. 31/6 net.

A Treatise on the Law and Practice affecting the Erection and Maintenance of Buildings in the Metropolis, with Special Chapters dealing respectively with the Cost of Building Work in and around London by **H. J. LEANING, F.S.I.**, and the Valuation and Management of London Property by **SYDNEY A. SMITH, F.S.I.** ; also the Statutes, Bye-laws and Regulations applying in London ; cross-references throughout.

Industrial Accidents and their Compensation.

By **G. L. Campbell, B.S.** *Crown 8vo. 4/- net.*

The Law affecting Engineers.

By **W. Valentine Ball, M.A. (Cantab.)**, Barrister-at-Law,
Joint Editor of "Emden's Building Contracts."

Demy 8vo. 10/6 net.

Foreign and Colonial Patent Laws.

By **W. Cranston Fairweather**, Chartered Patent Agent.

Demy 8vo. 10/6 net.

This is a compendium of Patent practice in every British possession and in every foreign country which appears on the map. The information given is in large part obtained from official sources, and is presented in a series of articles—one for each State—revised so far as is possible by agents practising in the States in question.

Patents, Designs and Trade Marks : The Law and Commercial Usage.

By **Kenneth R. Swan, B.A. (Oxon.)**, of the Inner Temple,
Barrister-at-Law.

Ex. Crown 8vo. 6/- net.

Inventions and Patents in America.

By **Philip E. Edelman.** *Size, Demy 8vo.*

The Arbitration Clause in Engineering and Building Contracts.

BY **E. J. Rimmer** (Barrister-at-Law), M.Inst.C.E.,
etc. Crown 8vo. 2/- net.

Miscellaneous

Primer of Scientific Management.

BY **F. B. Gilbreth**, M.Am.Soc.M.E., with an Introduction
by **LOUIS D. BRANDEIS**. 4/- net.

Commercial Paints and Painting : A handbook for Architects, Engineers, Property Owners, Painters and Decorators.

BY **Arthur Seymour Jennings**,
Fellow of the Institute of British Decorators, etc.
22s. + xii pages. 47 Illustrations. Extra Crown 8vo. 6/- net.

Soft Soldering, Hard Soldering, and Brazing :

A practical treatise on tools, materials, and operations,
for the use of Metal Workers, Plumbers, Tinnern,
Mechanics and Manufacturers.

BY **James F. Hobart**, M.E.
203 pages. 62 Illustrations. 4/- net.

Motion Study :

A METHOD FOR INCREASING THE EFFICIENCY OF THE WORK-
MAN. BY **F. B. Gilbreth**, M.Am.Soc.M.E. 4/6 net.

How to do Business by Letter and Advertising.

BY **Sherwin Cody**. 5/- net.

Natural Rock Asphalts and Bitumens :

THEIR GEOLOGY, HISTORY, PROPERTIES AND INDUSTRIAL
APPLICATION.

BY **Arthur Danby**, Chemist and Public Consultant on Rock
Asphalt and Bitumen.

Illustrated. Crown 8vo. 244 + ix pages. 8/6 net.

Water, its Purification and Use in the Industries.

BY **W. W. Christie**, M.Am.S.M.E., M.Am.S.C.E.
230 pages. 70 Illustrations. 8/6 net.

Spanish-English, English-Spanish Dictionary of Railway Terms.

By **André Garcia.** 12/6 net.

Seasonal Trades. BY **Arnold Freeman.** 7/6 net.

International Language and Science.

CONSIDERATIONS ON THE INTRODUCTION OF AN INTERNATIONAL
LANGUAGE INTO SCIENCE.

Translated by **Prof. F. G. Donnan.** Demy 8vo. 2/- net.

Forecasting Weather. BY **Sir W. N. Shaw, F.R.S., Sc.D., etc.,** Director of the Meteorological Office, London.

Illustrated with Maps, Charts and Diagrams. 12/6 net.

From the Introduction: "The arrangement which has been followed in this work is first to explain and illustrate the construction and use of synoptic charts and the method of forecasting by their means. I have dealt with special departments of the work of forecasting, such as gales and storm-warnings, anti-cyclonic weather, land and sea fogs, night frosts, colliery warnings, forecasts for aeronauts. . . . A chapter has been devoted to statistical methods for long period and seasonal forecasts."

Structural Geology. BY **C. K. Leith.**

169 + viii pages. 68 Illustrations. Demy 8vo. 6/6 net.

Vital Statistics Explained.

By **Joseph Burn, F.I.A., F.S.I.**

Illustrated. 144 + xvi pages. Demy 8vo. 4s. net. (THE CHADWICK LIBRARY.)

Modern Astronomy.

Second Edition.

BEING SOME ACCOUNT OF THE REVOLUTION OF THE LAST
QUARTER OF THE CENTURY.

By **Prof. H. H. Turner, F.R.S.** *Illustrated.* Cr. 8vo. 2/6 net.

Time and Clocks :

A DESCRIPTION OF ANCIENT AND MODERN METHODS OF
MEASURING TIME. BY **H. H. Cunyngname, M.A., C.B.**

Illustrated. Crown 8vo. 2/6 net.

The Limitations of Science.

By **Louis T. More, Ph.D.,** Professor in the University of
Cincinnati.

Cr. 8vo. 6/6 net.

CONTENTS:—Science as a Symbol and a Law. The Metaphysical Tendencies of Modern Physics. Descartes and his Influence on Recent Science. The Scientific Method. The Classical and the New Mechanics. Scepticism and Idolatry in Science. Science as the Arbiter of Ethics. Index.

Miscellaneous—continued.

The Seven Follies of Science. By John Phin.

A new and enlarged Edition. Illustrated. Demy 8vo. 5/- net.

A popular account of the most famous scientific impossibilities, and the attempts which have been made to solve them. To which is added a small budget of interesting paradoxes, illusions, and marvels.

Perspective : An Elementary Text-book.

By **B. J. Lubschez, M.Am.I.A.**

88 pages. 32 Illustrations. 6/- net.

Colour and Its Applications.

By **M. Luckiesh**, Physicist, Nela Research Laboratory,
National Lamp Works of General Electric Co.

129 Illustrations. 4 Color Plates.

CONTENTS:—Light. The Production of Color. Color-Mixture. Color Terminology. The Analysis of Color. Color and Vision. The Effect of Environment on Colors. Theories of Color Vision. Color Photography. Color in Lighting. Color Effects for the Stage and Displays. Color Phenomena in Painting. Color Matching. The Art of Mobile Color. Colored Media. Index.

Public Ownership of Telephones.

By **A. N. Holcombe.** 8vo. 8/6 net.

"We commend this book to the notice of all interested in the study of telephone development and administration."—*Electricity*.

British Railways : A Financial and Commercial Study.

By **W. R. Lawson**, Chairman of the Railway Shareholders' Association.

320 + xxxvii pages. Extra Crown 8vo. 6/- net.

Panama :

ITS CREATION, DESTRUCTION, AND RESURRECTION.

By **Philippe Bunau-Varilla.**

Illustrated. Royal 8vo. 12/6 net.

Good Engineering Literature.

By **Harwood Frost, M.Am.Soc.M.E.** Crown 8vo. 4/6 net.

Essays Biographical and Chemical.

By **Professor Sir William Ramsay, K.C.B., LL.D., F.R.S., D.Sc., etc.** Demy 8vo. 7/6 net.

The Curves of Life. Being an Account of Spiral Formations and their Application to Growth in Nature, to Science, and to Art.

By **Theodore Andrea Cook, M.A., F.S.A.**

415 Illustrations and 11 Plates. Royal 8vo. 470 + xxvii pages. 12/6 net.

INDEX OF TITLES

A.

ADJUSTMENT OF OBSERVATIONS by the Method of Least Squares, 29
Aerial Flight, 20
Aeroplane Patents, 20
Agglutinants and Adhesives of all Kinds for all Purposes, 50
Air and Aviation, Resistance of the, 19
Aircraft in Warfare, 19-20
Arbitration Clause in Engineering and Building Contracts, The, 57
Astronomy, Modern, 58
Atoms, 42

B.

Basic Open-Hearth Steel Process, The, 17
Biology, Outlines of Evolutionary, 54
Bitumens and Natural Rock Asphalts, 57
Boiler Draught, 11
Boiler Explosions, Collapses, and Mishaps, 10
Building in London, 29, 56
Business, How to do, by Letter and Advertising, 57

C.

Calculus and its Applications, The, 47
Cams, and the Principles of their Construction, 15
Cement and Concrete, 27
Cement, Concrete and Bricks, The Chemistry of, 46
Cement Specifications, A Treatise on, 25
Cement Testing, A Manual of, 26
Centrifugal Pumps, 16
Chadwick Library, The, 2
Chemical Annual, Van Nostrand's, 44
Chemical Calculations, 42
Chemical Re-agents, Their Purity and Tests, 44
Chemical Theory and Calculations, 41
Chemistry, A New Era in, 45
Chemistry and Physics of Building

Chemistry and Technology of Printing Inks, The, 41, 50
Chemistry of Dyeing and Bleaching of Vegetable Fibrous Materials, The, 45
Chemistry of Paints and Paint Vehicles, The, 44
Chemistry of the Coal Tar Dyes, The, 46
Chemistry of the Oil Industries, 48
Chemistry of the Rubber Industry, The, 46
Chemistry Old and New, Some Fundamental Problems of, 40
Chemistry, Text-Book of Elementary, 45
Circular-Arc Bow Girder, A Study of the, 28
Civil Engineers' Pocket Book, 27
Coal, 13
Cold Storage, Heating and Ventilating on Board Ship, 21
Colloidal and Crystalloidal State of Matter, The, 46
Colour and Its Applications, 59
Commercial Paints and Painting, 49, 57
Compressed Air: Its Production, Uses and Applications, 16
Contemporary Chemistry, 45
Continuous Current Engineering, 38
Cork: Its Origin and Industrial Uses, 50
Corpuscular Theory of Matter, The, 42
Cotton Seed Products, 49
Cranes: Their Construction, Mechanical Equipment and Working, 15
Curves of Life, The, 59

D.

Dairy Laboratory Guide, 55
Designing, Theory and Practice of, 29
Dies: Their Construction and Use for the Modern Working of Sheet Metals, 15
Diesel Engine for Land and Marine Purposes, The, 8
Direct and Alternating Current Test-

INDEX OF TITLES—*continued.*

D.-S. Series of Technical Dictionaries
in Six Languages, The, 7
Dynamics of Mechanical Flight, 19
Dynamometers, 13

E.

Elastic Arch, The, 27
Electric Arc Phenomena, 42
Electric Cables and Networks, The
Theory of, 37
Electric Central Station Distribution
Systems (American), 36
Electric Cooking, Heating, Clean-
ing, etc., 35
Electric Furnaces, 38
Electric Lamps, 38
Electric Mechanism, 35
Electric Mine Signalling Installa-
tions, 34
Electric Power and Traction, 37
Electric Power, Application of, 10
Mines and Heavy Industries, 23
Electric Railway
Electric Railways
Practically Treated, 37
Electric Wiremen's Manuals, 3
Electrical Conductivity and Ionization
Constants of Organic Compounds,
36
Electrical
Electrical Machinery, Testing, 37
Electrical Nature of Matter and Radio-
Activity, 43
Electricity: A Text-Book of Applied
Electricity, 36
Electricity and Matter, 42
Electricity Through Gases, Discharge
of, 43
Electro-Chemistry, Experimental, 38
Electro-Metallurgy, 38
Electro-Thermal Methods of Iron and
Steel Construction, 17
Enamelling, 51
Energy-Diagram for Gas, The, 9
Engine Tests and Boiler Efficiencies,
11
Engineering Literature, Good, 59
Engineering Workshops, Machines
and Processes, 15
Entropy, 16, 39
Essays, Biographical and Chemical, 59
Extinct Animals, 53
European Animals, 53

F.

Farm Animals, 56

Field Engineer, The, 25
Flying Machine from an Engineering
Point of View, The, 20
Food Adulterants, The Detection of
Common, 45
Forecasting Weather, 58
Foundations and Machinery Fixing,
28
Foundry Practice, General, 17
Frozen Meat Trade, History of the, 51
Fuel, Gas and Water Analysis for
Steam Users, 13
Fuel, Introduction to the Study of, 12

G.

Gas Engine, The, 9
Gas Engine Construction, 9
Gas Engine Design, 9
Gas Engines, High Power, 9
Gas-Engineering Practice (American),
9
Gas, Gasoline, and Oil Engines,
including Gas Producer Plants, 10
Gas, Town, and its Uses, 10, 39
Gas Turbine, The, 9
Gas Works Plant and Machinery,
British Progress in, 10
Geographic Environment, Influences
of, 54
Glasgow Text-Books of Civil Engi-
neering, The, 4
Glass Manufacture, 49
Glass Processes, Decorative, 49
Glues and Gelatine, 50
Graphic Statics, Elements of, and
General Graphic Methods, 21
Graphical Determination of Earth
Slopes, Retaining Walls and
Dams, 28
Grass Holding, To Work a, at a
Living Profit, 55

H.

Hardening, Tempering, Annealing
and Forging of Steel, 18
Heat Power-Plants, The Economic
and Commercial Theory of, 16
Hydraulics and its Applications, 22
Hydraulics, Text-Book of, 22
Hydroelectric Developments and
Engineering, 23, 37
Hydrogenation of Oils, The, 43

I.

Identification of Organic Compounds,

INDEX OF TITLES — *continued*.

India-Rubber and its Manufacture, 50
 Industrial Accidents and their Compensation, 56
 Industrial Chemistry, 40
 Industrial Chemistry, Outlines of, 2
 Industrial Electrical Measuring Instruments, 37
 Inorganic Chemistry, Practical Methods of, 45
 Integration by Trigonometric and Imaginary Substitution, 47
 Internal Combustion Engine, The, 8
 Internal Combustion Engines, The Construction and Working of, 8
 Internal Combustion Engines, The Design and Construction of, 8
 Internal Combustion Engine, Primer of the, 8
 International Language and Science, 58
 Inventions and Patents in America, 56
 Ionization of Gases by Collision, The Theory of, 43
 Iron and Steel (Hudson and Bengough, "Outlines of Industrial Chemistry" series), 17
 Iron and Steel (Stansbie, "Westminster" series), 18
 Iron and Steel, Forging of, 14
 Irrigation: Its Principles and Practice as a Branch of Engineering, 32
 Irrigation Works, 32
 Irrigation Works, Notes on, 32
 Irrigation Works, The Practical Design of, 32

L.

Laboratory and Factory Tests in Electrical Engineering, 37
 Law affecting Engineers, The, 52, 56
 Leather, Manufacture of, 49
 Lettering, 52
 Life Histories of Northern Animals, 54
 Life in America, Distribution and Origin of, 53
 Limitations of Science, The, 58
 Linseed Oil and other Seed Oils, 50
 Liquid Air and the Liquefaction of Gases, 44
 Liquid and Gaseous Fuels, 13
 Liquid Fuel and its Apparatus, 12
 Liquid Fuel and its Combustion, 13
 Living Plant, The, 53

M.

Malleable Cast Iron, 17
 Marine Double-ended Boilers, 11
 Marine Engine Design, 21
 Masonry Applied to Civil Engineering, 28
 Mathematics for the Practical Man, 47
 Measurements, Theory of, 42
 Mechanical Appliances, 14
 Mechanical Movements, Powers, Devices and Appliances, 14
 Mechanic, The, 14
 Mechanic's, The, Practical, 47
 Mechanics of Materials, The Elements of, 14
 Mechanics, Theory and Practice of, 13
 Metallurgy, 3
 Microscopy, Principles of, 43
 Mineral and Aerated Waters, and the Machinery for their Manufacture, 49
 Mining and Mine Ventilation, 23
 Motion Study, 57
 Motor Car Engineering, Text-Book of, 18
 Motor Pocket Book (O'Gorman's), 18
 Motor Vehicles and Motor Boats, 18
 Municipal and Sanitary Engineering, The, 18
 The Encyclopedia of British Progress in, 31

N.

Nature Student's Note-Book, The, 53
 Naval Machinery, Handbook for the Care and Operation of, 22, 52
 Nitrocellulose Industry, The, 46

O.

Oil Fuel Equipment for Locomotives, 12, 24
 Overhead Transmission Lines, and Distributing Circuits, 34

P.

Painting, Materials for Permanent, 46, 51
 Panama: Its Creation, Destruction, and Resurrection, 59
 Paper, The Manufacture of, 40

INDEX OF TITLES—*continued.*

Perspective: An Elementary Text-Book, 59
 Physico-Chemical Theory, Applications of to Technical Processes, etc., 48
 Physical Chemistry, Exercises in, 44
 Physical Chemistry, Problems in, 41
 Physical Metallurgy, Introduction to the Study of, 17, 41
 Physics: A Text Book of, 44
 Plants and Ecology, 54
 Potato, The, 55
 Potters' Craft, The, 51
 Poultry Management on a Farm, 55
 Power, Natural Sources of, 16
 Power, Applications of the Principles of, to Road Transport, 27
 Practical Manuals for Practical Men, 3
 Precious Metals, The, 18
 Precious Stones, 51
 Precision Grinding, 15
 Pricing of Quantities, 29, 52
 Propagation of Electric Currents in Telephone and Telegraph Conductors, The, 33
 Proportion, Theory of, 47
 Pumps and Pumping Engines, British Progress in, 16
 Purchasing: Its Economic Aspects and Proper Methods, 48

Q.

Quaternions, as the Result of Algebraic Operations, 47

R.

Radio-Active Transformations, 43
 Radio-Activity and Geology, 42
 Radio-Telegraphy, 33
 Railway Locomotive, The, 25
 Railway Maintenance Engineering, 24
 Railway Shop Up-to-date, 25
 Railway Signal Engineering (Mechanical), 25
 Railway Spiral, The Practical, 24
 Railway Terms: Spanish-English, English-Spanish, Dictionary of, 25, 58
 Railways, British, 59
 Rainfall, Reservoirs and Water Supply, 30
 Refuse Disposal and Power Production, 31
 Reinforced Concrete, A Concise Treaty on, 26
 Reinforced Concrete and Concrete

Reinforced Concrete Bridges, 26
 Reinforced Concrete Compression Member Diagram, 26
 Reinforced Concrete, Properties and Design of, 26
 Reinforced Concrete Railway Structures, 24

S.

Sanitary Engineering (Modern), 31
 Science, The Seven Follies of, 59
 Science, Thresholds of, 5
 Scientific Management, Primer of, 57
 Searchlights: Their Theory, Construction and Application, 38
 Seasonal Trades, 58
 Sewage Disposal Works, 30
 Ship Form, Resistance, and Screw Propulsion, 21
 Shop Kinks, 15
 Silicates in Chemistry and Commerce, The, 40
 Simple Jewellery, 51
 Single-Phase Electric Railways, 34
 Sizing, Materials used in, 50
 Small Dust Destroyers for Institutional and Trade Refuse, 31
 Smoke Prevention and Fuel Economy, 13
 Soft Soldering, Hard Soldering, and Brazing, 57
 Soils and Manures, 55
 Soils: How to Handle and Improve Them, 55
 Solenoids, Electromagnets and Electromagnetic Windings, 35
 Solution of Railroad Problems by the Slide Rule, 24
 Solvents, Oils, Gums, Waxes, and Allied Substances, 50
 Stability and Equilibrium of Floating Bodies, 21
 Static Transformers, The Design of, 36
 Statical Calculations, Reference Book for, 52
 Steam Boilers: Their History and Development, 11
 Steam-Electric Power Plants, 37
 Steam Engine, A Manual of the High Speed, 10
 Steam Engine and Turbine, The, 11
 Steam Engine, The Modern, 10
 Steam, Flow of through Nozzles and Orifices, Experimental Researches on, 12
 Steam Pipes: Their Design and Construction, 11
 Steam Tables, The New, 12, 52
 Steel Bridges, The Design of Steel

INDEX OF TITLES—*continued.*

Steel - Framed Sheets, Practical Design of, 28
 Steel Rails: Their History, Properties, Strength and Manufacture, 24
 Stone Age in North America, The, 53
 Structural Design, The Elements of, 27
 Structural Geology, 58
 Superheat, Superheating, and their Control, 12
 Surveying and Field Work, 29-30
 Surveying, Practical, 30
 Switches and Switchgear, 35
 Switchgear Design, High and Low Tension, 35

T.

Tables of Multiplication, Division and Proportion, 52
 Telegraph Engineering, 32
 Telegraphic Transmission of Photographs, The, 33
 Telephones, Public Ownership of, 33, 59
 Test Methods for Steam Power Plants, 11
 Testing, A Handbook of, 14
 Textiles and their Manufacture, 50
 Thermodynamics, Applied, for Engineers, 39
 Thermodynamics, Experimental and Theoretical Applications of, to Chemistry, 39, 43
 Thermodynamics, Principles of, 39
 Thermodynamics, Technical, 39
 Thermodynamics, A Text-Book of, 39
 Timber, 29
 Time and Clocks, 58
 Toll Telephone Practice, 33
 Transmission Line Formulas, 35
 Trees, Indian, 54
 Tunnel Practice (Modern), 29

Tunnel Shields and the Use of Compressed Air in Subaqueous Works, 28
 Turbine Practice and Water Power Plants (Modern), 23
 Turbines Applied to Marine Propulsion, 22

U.

Una-flow Steam Engine, The, 10
 Universe, The, and the Atom, 42

V.

Vapours for Heat Engines, 43
 Vital Statistics Explained, 58

W.

Water Hammer in Hydraulic Pipe Lines, 22
 Water: Its Purification and Use in the Industries, 57
 Water Pipe and Sewage Discharge Diagrams, 31
 Water Purification and Sewage Disposal, 30
 Water Softening and Treatment, 15
 Welding and Cutting Metals by the Aid of Gases or Electricity, 18
 "Westminster" Series, The, 6
 Wireless Telegraphy, Maxwell's Theory and, 33
 Wiring of Buildings, Internal, 38
 Wood Pulp, 51
 Wool Growing and the Tariff, 54

Z.

Zoology and Entomology, Economic, 53

